# DATA ANALYSIS OF THE LOOP MARINE AND ESTUARINE MONITORING PROGRAM, 1978–95

## VOLUME 4: ZOOPLANKTON AND ICHTHYOPLANKTON

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# DATA ANALYSIS OF THE LOOP ESTUARINE AND MARINE MONITORING PROGRAM, 1978-95

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## VOLUME 4: ZOOPLANKTON AND ICHTHYOPLANKTON

**Final Report**

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# EXECUTIVE SUMMARY

## Introduction

### Louisiana Offshore Oil Port

The Louisiana Offshore Oil Port (LOOP) facilities in coastal Louisiana provide the United States with the country's only superport for off-loading deep draft tankers. The facilities are located in Lafourche Parish in southeast Louisiana, south of New Orleans and adjacent offshore waters west of the Mississippi River Delta. The superport complex consists of an offshore marine terminal (Figure ES-1; Station 708) located about 30 km from the mainland in the Gulf of Mexico, an onshore storage facility at the Clovelly salt dome near Galliano about 50 km inland from the coast (Figure ES-1; Station 38), and a large diameter pipeline system including a pumping booster station near Fourchon onshore to deliver oil to the storage facility. A small-boat harbor and logistics facility is located at Port Fourchon, on Bayou Lafourche.

### Monitoring Program

The proposed construction and use of these facilities led to questions about various consequential environmental impacts arising from the following activities: (1) creation of the salt dome storage facility required solution mining of storage caverns within the Clovelly salt dome and the creation of a 101 ha brine storage area (brine is pumped back into the storage cavity to maintain the integrity of the caverns, as well as to float the oil back out) and would result in freshwater (used to excavate the salt dome) bypassing the estuary on its way to the offshore disposal site (Figure ES-2; Station 36); (2) the brine (average 200 ppt) and other leachates are discharged 4.8 km offshore at the Diffuser facility (Figure 2: Station 36) into a major US fishing zone; (3) creation of a pipeline corridor and subsequent related activities resulted in direct and indirect wetland losses and possible changes in hydrology; (4) subsequent logistical or economic activities during and after facility operations; and (5) small and large oil spills. Because of the potential risks associated with the construction and

operation of the superport ( e.g. bringing the world's largest oil tankers to one of the most productive fisheries resources in the world), both state and federal licenses required environmental monitoring of LOOP construction and operational activities. The environmental monitoring program (EMP) was developed under mandate of the Superport Environmental Protection Plan (revised, 1977), a regulation of the State of Louisiana implementing the Offshore Terminal Act. The Louisiana Department of Wildlife and Fisheries collected the data related to estuarine/marine monitoring components from 1978 to 1995. This report is the zooplankton and ichthyoplankton component in a series of five reports that analyze the impacts of LOOP construction, operation, and maintenance on the estuarine/marine environment.

**Study Objectives**

The objectives of this analysis are directly related to the original objectives of the LOOP, Inc. Environmental Management Plan (EMP 1986: section 3.1, page 8), which were:

(1) to obtain seasonal environmental and ecological data so that conditions existing during operation can be related to historical baseline conditions;

(2) to detect during the operation of the project any adverse alterations or damages to the environment so that corrective action can be taken as soon as possible;

(3) to obtain sufficient data to determine the cause of environmental damages or alterations so that responsibility can be properly placed; and,

(4) to provide information in order to evaluate long and short-term impacts of the project.

Therefore, the main effort of Task 2 is to conduct appropriate statistical analyses on the existing data collected by LDWF to determine the impact (i.e., test the null hypothesis of no difference or no impact) of the LOOP pipeline construction and operation on the estuarine and nearshore zooplankton and ichthyoplankton by testing whether the temporal trends at the monitoring impact stations are the same as in the control areas. This is tested with the TIMExTREATMENT interaction term in a standard Before-After, Control-Impact (BACI) design. However, tests were not limited to the BACI design. In the absence of the

appropriate Before data set(s), we conducted a During-After, Control-Impact statistical design and in one case simply a Control-Impact design.

## Methods

### The data base

Over the course of the zooplankton and ichthyoplankton field sampling program (February 1978 to December 1995), a total of 97 plankton stations were sampled at one time or another at environments ranging from freshwater to mid-continental shelf. Four (4) sampling gears and six (6) different sampling protocols were employed over the duration of the study. To examine the potential impacts of floating oil, surface tows were taken at inshore and offshore stations. Within inshore and offshore waters a 0.5 m plankton net with either 0.80 mm or 0.153 mesh was towed for one minute. In offshore waters and at one inshore station, a 1 m plankton net with 0.363 mm mesh was towed for 3-5 minutes. In deeper offshore waters, bongo nets were used to sample zooplankton and ichthyoplankton occupying various divisions of the water column where effects of aged and dispersed oil would most likely occur. This sampling involved various sampling protocols utilizing a 60-cm, hinged, paired bongo net frame (opening and closing) with 0.363 mm mesh netting towed in a horizontally stratified or oblique fashion for approximately 3-5 minutes.

Zooplankton and ichthyoplankton sampling was conducted monthly at most stations with quarterly sampling at others. Only seven stations were sampled continuously from early in the study, February to July 1978, to near its completion. At all sampling stations temperature, conductivity, salinity and dissolved oxygen profiles were taken.

### Modifications to the Sampling Program

The zooplankton sampling program was revised a number of times, as the environmental program emphasis shifted from monitoring LOOP facility and pipeline construction and brine discharge, to monitoring potential impacts of ongoing operations including oil spill and

dispersant use. Additional changes were implemented to streamline the sampling program (decrease field effort and sample processing time) and to alleviate the accumulating backlog of unsorted and unidentified plankton collections.

Zooplankton biomass (standing stock) estimates (ml/m$^3$) and selected decapod crustacean taxa were identified and enumerated from plankton collections over most of the duration of the project and consisted of the early developmental stages of *Penaeus* spp., *Callinectes* spp., and *Portunus* spp. Copepoda, Polychaeta, Gastropoda were often recorded as well. Ichthyoplankton identification for all the major taxa were mostly complete after January 1981.

## Results and Discussion

For a listing of the types of statistical analyses conducted and their time periods, control-impact station groupings, and the taxa considered see Table ES-1. There were numerous significant or marginally significant ($P = \leq 0.1$) seasonal, annual and spatial main effects and interactions which were identified that were not directly related to LOOP operations or impacts (Table ES-2).

Only a few statistical analyses had significant or marginally significant Direct LOOP Impact implications (DLI; Table ES-2), while another test had results which appeared to have Indirect LOOP Impacts (ILI; Table ES-2). Some test results appear to be related to oil discharge or spills and/or subsequent clean up activities while others to the construction phase. The discussion of marginally significant statistical results is environmentally, ecologically and biologically meaningful, because they clearly suggest that those parameters are sensitive to LOOP - related environmental perturbations.

The zooplankton biomass data set was by far the most complete (longest times series and largest sample size) and had a greater number of significant and/or marginally significant test results. The most relevant test finding resulted from the BACI Long-term, Inshore, Combined Impacts Model (2/78 to 12/95) which had the Clovelly oil spill data as a

covariate. Oil as a covariate proved to be marginally significant (P = 0.0983) and showed an inverse (negative) relationship with zooplankton biomass (Table ES-2; Figure ES-3). Another relevant finding involving zooplankton biomass occurred within the DACI Inshore, Long-term Construction Impacts Model which had a marginally significant (P = 0.0428) During-After, Control-Impact interaction whereby mean zooplankton biomass at Impact stations was greater than the Controls (2.17 vs. 1.70 ml/$m^3$) During the construction phase, but was lower than Control estimates (1.40 vs. 1.81 ml/$m^3$) After construction. Perhaps construction disturbances, initially stimulated the standing stock of the zooplankton population which later was depressed by the long-term combination of perturbations. Other marginally significant test results were more difficult to explain in terms of Indirect LOOP impacts, such as the During-After, Control-Impact interaction (P = 0.0566; Table ES-2) seen within the zooplankton biomass data in the DACI Brine Diffuser model run on the HL data set over the May 1980 to July 1986 time period. Mean zooplankton biomass at Impact stations was less than Controls within the During period, but was greater than Controls After (Figure ES-4).

As with the oil, brine and construction analyses conducted inshore, the offshore LOOP Terminal Oil Impact analyses, which used the platform oil spill data set as a covariate, produced a number of significant and marginally significant temporal (in this case seasonal and annual) results (Table ES-2). However, two (2) test results relate directly to the discussion of LOOP-related environmental impacts. Densities for *Anchoa* spp., a very abundant coastal taxonomic group, displayed a marginally significant (P = 0.0991; Figure ES-5) negative (inverse) relationship with oil spill data as a covariate. This negative relationship was not strong and appeared to be influenced by five large oil spill points. In addition, this negative relationship was not additionally supported by other significant Control-Impact (spatial) interactions, yet the analyses had sufficient enough power to identify significant temporal relationships. The second noteworthy impact-related finding occurred with *Chloroscombrus chrysurus*, another very abundant coastal species. *Chloroscombrus chrysurus* displayed a marginally significant Control-Impact-Year Season interaction (P = 0.0271; Figure ES-6). This statistical result was mostly a reflection of the mean density values for the Control stations during the summer/fall time period in 1981

(13.97 larvae/100m$^3$) and 1985 (45.27) being an order of magnitude greater than the Impact station densities (3.84 and 0.81, respectively). Control station densities were also an order of magnitude greater than Impact during the high abundance peak in the spring/summer period of 1982 (63.82 vs. 4.24 larvae/100 m$^3$, respectively). Such a statistical finding may be indicative of environmental impact(s) associated with less clearly defined, spatial and temporal events such as relatively small, chronic oil spills.

## Conclusions

In summary, the negative relationship between the Clovelly oil spill data and zooplankton biomass; and the zooplankton biomass During-After, Control-Impact interaction within the DACI Inshore Long-term Construction Model provide the clearest implications for LOOP-related impacts inshore. In the coastal/offshore environment, there were two (2) indicators of potential environmental impact from LOOP-related activities. The Control-Impact, Offshore LOOP Terminal Oil Impact analysis of zooplankton and ichthyoplankton densities used platform oil spill data as a covariate, and season and year as main effects. The negative relationship between spilled LOOP offshore terminal oil and *Anchoa* spp. densities and the Control-Impact-Year-Season interaction within the *Chloroscombrus chrysurus* analysis, both indicate that these taxa are sensitive to LOOP-related environmental Impact. Clearly when the data sets were large, continuous or involved very abundant taxa, the analysis was sensitive enough to observe potential environmental impact(s).

## Considerations for Continued Sampling

This section is a summary of a detailed discussion that can be found in Task 3. We felt it was useful to include it here since some readers may only review the Executive Summary or the Task 2 report. The data sets examined indicated that the current monitoring program, as identified in the original environmental management plan, worked i.e., we were able to document spatial and temporal (seasonal and annual) trends and some impacts; however, some readjustments are desirable based on the experience of the last 18 years.

Environmental monitoring is intended to provide data for the detection of impact (should it occur) and to provide a baseline for restoration in the event of an impact. An impact may be associated with clearly defined temporal and spatial events, such as construction and post-construction stages, in which case clearly defined periods can be tested as "before" and "after" categories facilitating statistical testing. Impacts may also be associated with less clearly defined, temporal and spatial events such as relatively small, chronic oil spills. The gradual changes occasioned by this type of event are much more difficult to detect and require long, continuous periods of sampling to develop trend analyses. In the case of the LOOP project, the most important reason for monitoring is to provide a continuous baseline of the status of the environment as a precaution against a future catastrophic event. A continuous baseline of data preceding a catastrophic event is a necessary condition to determine impact and the measures necessary for mitigation and restoration. For example, continued environmental monitoring is necessary, because it has been predicted that: an average of between 3,740 and 5,400 barrels/yr would be spilled; that within a 24 year period there would be a single spill of at least 10,000 barrels of oil; and that a maximum credible spill of 240,000 barrels will occur once over a period greater than 50 years (DOT, USCG, 1976). While the LOOP record of accidental oil spills is below these prediction levels, the oil risk estimates point to the need for credible pre-spill baseline data. Furthermore, a number of our significant or marginally significant test results are explained by strong seasonal and annual abundance changes through time (Before-After or During-After interactions or Control-Impact-Year and Control-Impact-Year-Season interactions). The presence of such abundances trends only reinforce the dynamic properties of this unique and productive deltaic system and the need to continue to monitor and track how the ecosystem is changing/evolving through time.

In addition, the extent and importance (historically, culturally, and economically) of our renewable fisheries resources to Louisiana and the nation should not be taken for granted nor their fragility underestimated, if they are to be sustained for future generations. The coastal marshes of Louisiana are one of the most productive ecosystems in the world, supporting a wide variety of estuarine-dependent organisms. Louisiana leads fishery production within the northern Gulf of Mexico and is second only to Alaska among all states.

The fish community of the Barataria Bay estuarine system is the most diverse of any estuary in Louisiana with 191 species from 68 families (Condrey et al. 1995).

Bearing in mind the responsibility above and the experience the last 18 years has brought, we make the following sampling program. We recommend reducing the number of sampling gears from 4 to 3, the number of sampling protocols from 6 to 3, and the total number of sampling stations from 97 (throughout history of study or from 19 - 21 in recent years) to a total of 14. The following monthly sampling stations should be maintained: pipeline and Clovelly impact stations 7, 15 and 38 and control 12, 13, 14 - all HL sampling stations; Diffuser impact station 36 and control 21 and 22 - all OM sampling stations, and LOOP Offshore Terminal impact stations 55 (OM) and 708 (BH) with controls 52 (OM) and 704 and 706 (BH). These stations have the strongest continuous data sets and are, therefore, in the best position to accomplish EMP Objectives 1 through 4. If the Diffuser brine pumping schedule is expected to remain at current low levels, then Diffuser sampling could possibly be discontinued, which would further lower the total number of stations sampled to 11. All station sampling should be replicated a minimum of 3-5 times so as to better estimate the within station variability and thereby increase the power and resolution of statistical analyses, which is in furtherance of EMP Objectives 2 and 3.

Monthly samples should be collected each year (with extreme care taken toward ensuring long term preservation) but routinely worked up (taxonomically) every other year. This complete sample sorting and identification of all larval fish (density, no./100m$^3$), zooplankton biomass (estimates from displacement volume methodology - ml/m$^3$), and the commercially - important decapods (i.e., *Penaeus* spp. and *Callinectes* spp. densities - no./m$^3$) and *Portunus* spp. would be available for an alternating year time series (trend connection) going back to the present 18 year data set. At the same time the availability of archived samples would insure that at any given point in time, if there were to be a major oil spill, the subsequent BACI statistical analysis would have at least a two-year Before period of available samples. The BACI statistical design would also greatly benefit from the increased power that the station sample replication would bring to bear, which is in furtherance of all EMP Objectives.

Supporting environmental data are needed to supplement/complement the zooplankton and ichthyoplankton sampling program. Monthly water column profiles at each station for temperature, salinity, conductivity, turbidity, dissolved oxygen, and surface estimates for chlorophyll are needed. In addition, brine and oil spill data for inshore (Clovelly) and offshore LOOP Diffuser and Terminal sites are needed for future analyses as covariates, which are in furtherance of EMP Objectives 1 through 4. Moored current meter arrays around the LOOP offshore terminal are needed to guide adaptive zooplankton and ichthyoplankton sampling responses to predicted major offshore oil spills, which would be in furtherance of EMP Objective 3.

Resource managers need to formulate a specific oil spill response plan for the LOOP Offshore Terminal that would include sampling at the long-term monitoring stations in that area at an increased frequency and with additional replication (EMP Objective 2). In addition, any new construction or planned discharge scenario should have an adequate Before sampling data collection period (2-3 years of pre-Impact data collection) in furtherance of EMP Objectives 1 through 4.

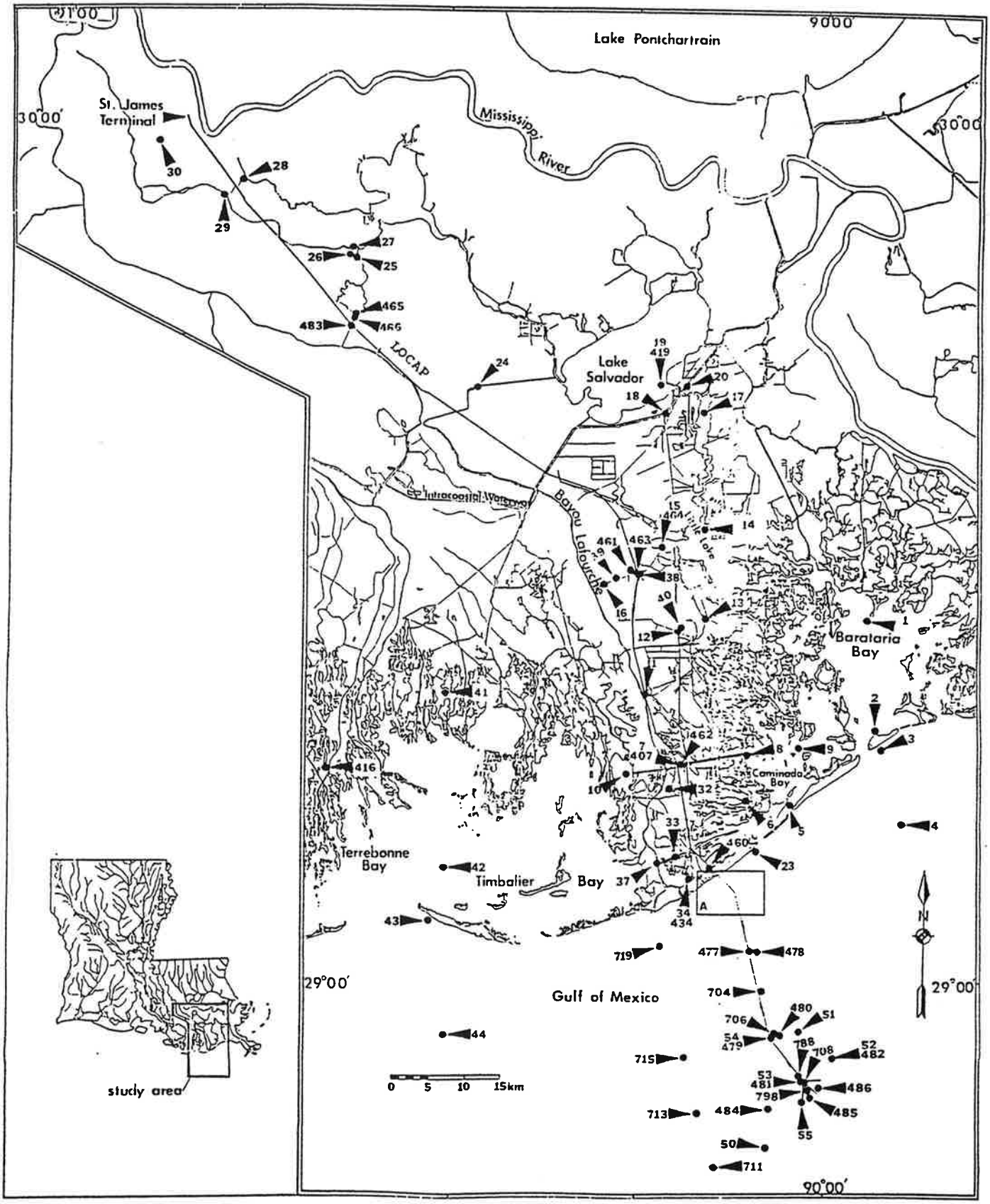


Figure ES-1. General map of the study area including the alignment of the LOOP (and LOCAP) pipelines. Zooplankton and ichthyoplankton stations are indicated by arrow and number. Box A represents the LOOP brine diffuser area and is shown in detail in Figure 2. (scale = 1:494,000). Modified after Hanifen (1987; Figure 1.2).

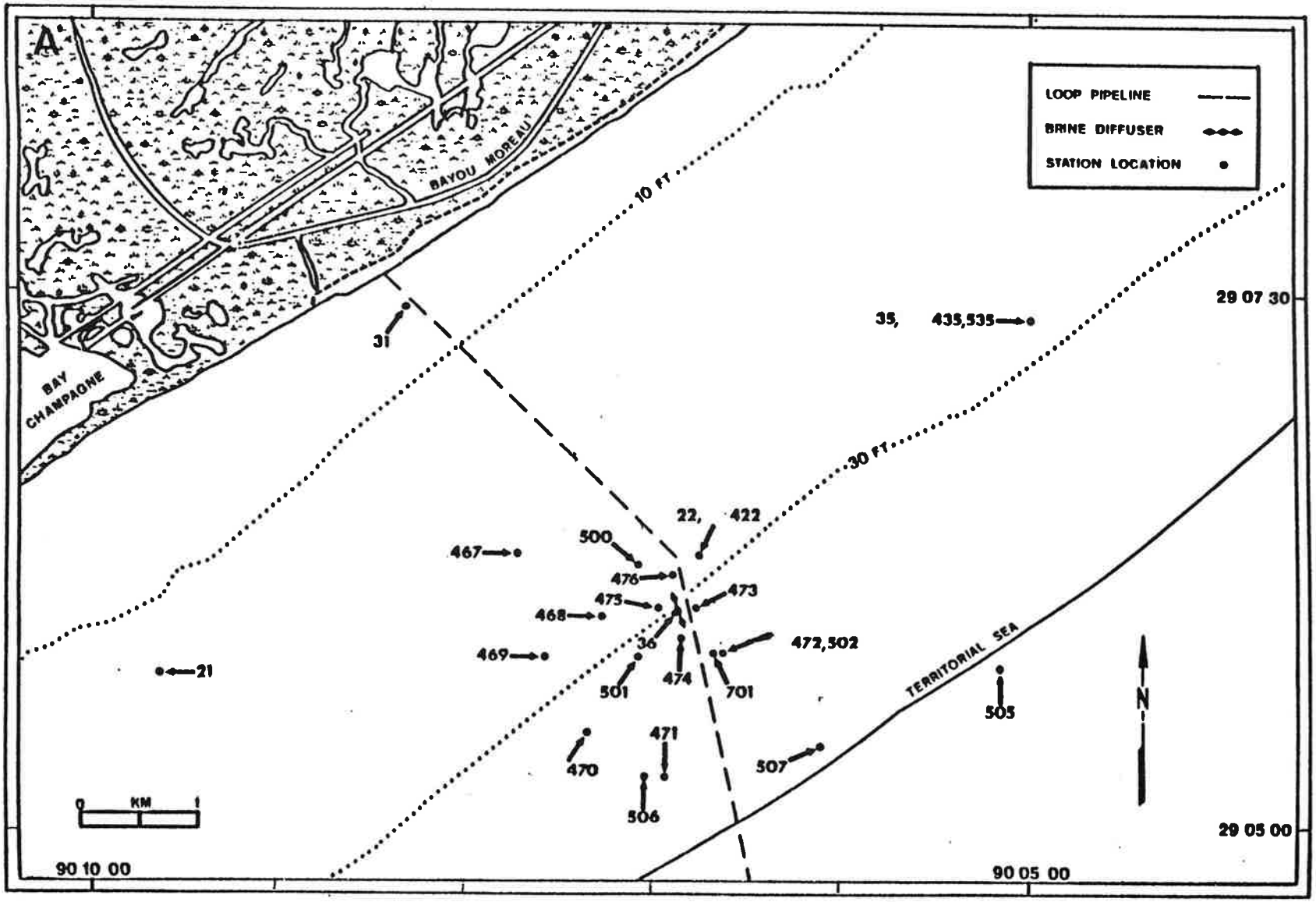


Figure ES-2. Zooplankton and ichthyoplankton sampling stations in the vicinity of the LOOP brine diffuser (station 36) off the central Louisiana coast. (scale = 1:51,000). Modified after Hanifen (1987; Figure 1.3).

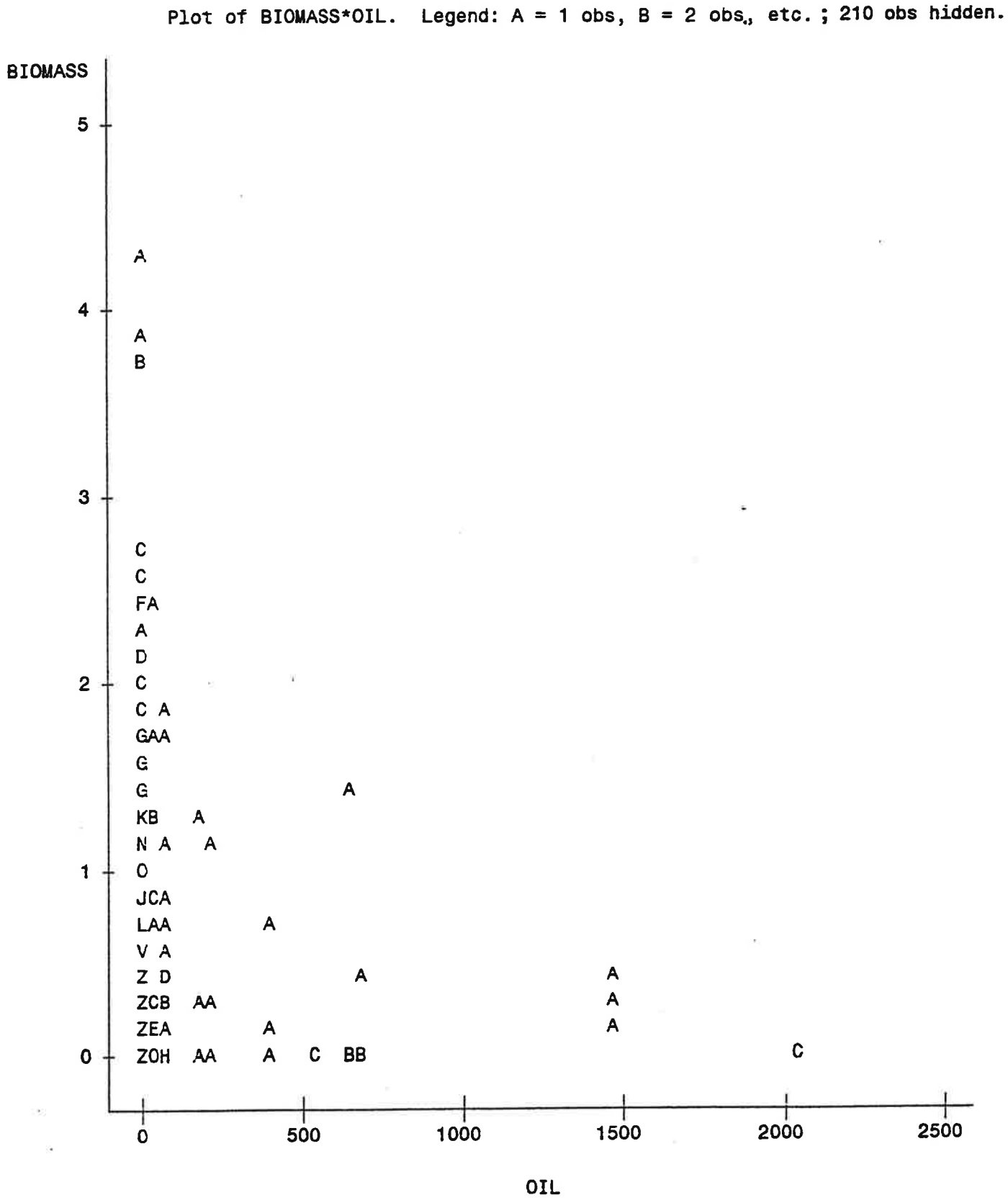


Figure ES-3. Zooplankton biomass estimates (ml/m$^3$) from impact stations associated with the Clovelly Salt Dome Storage Facility (i.e., stations 15, 16, 38, and 39) plotted against inshore LOOP - related oil spill data (gallons). See Table 4 and 5 for additional information.

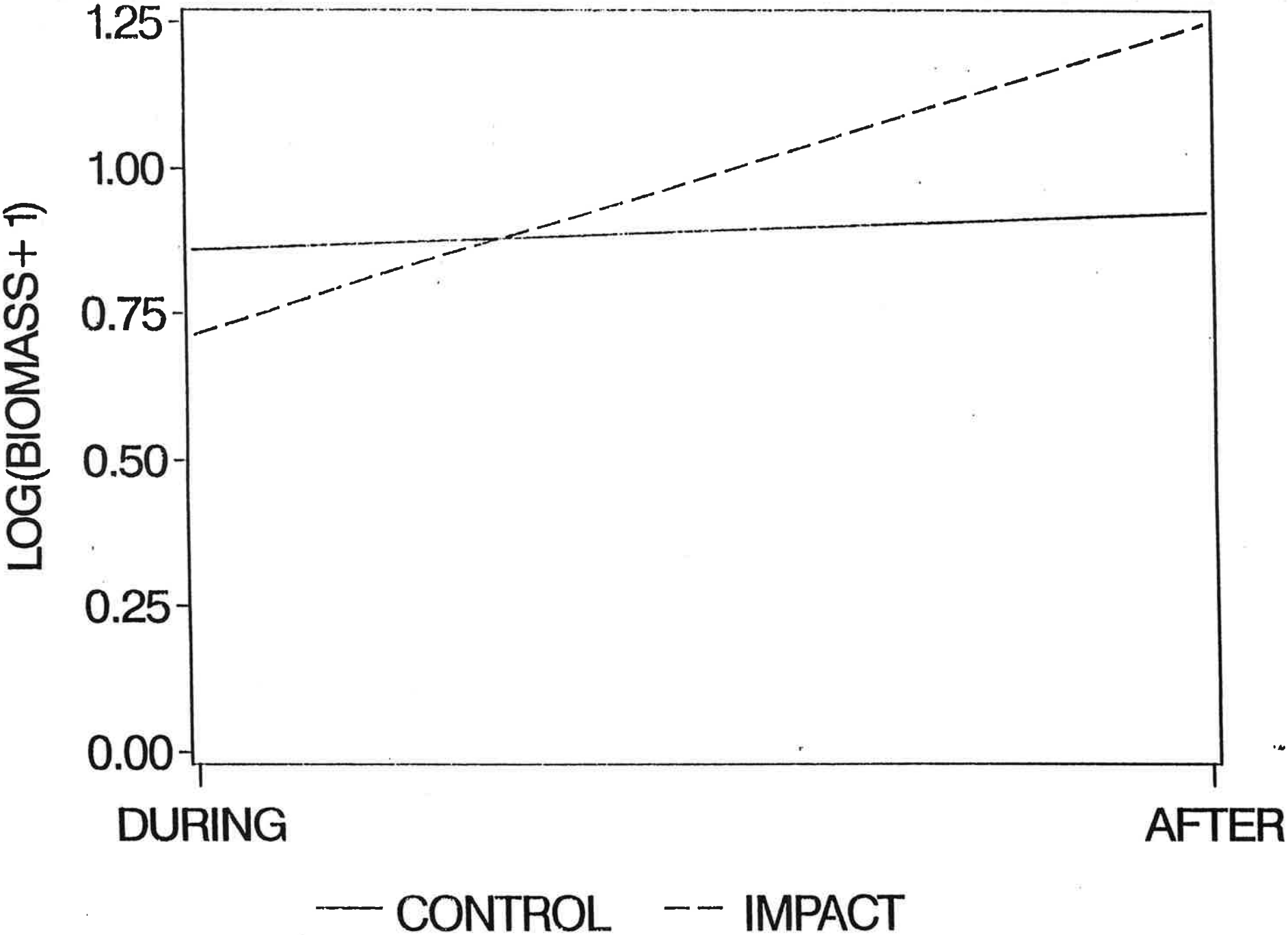


Figure ES-4. Log-transformed zooplankton biomass estimates (displacement volumes) by season for the Control and Impact stations from the DACI reduced, long-term, offshore Diffuser impacts model run on HL stations only. See Tables 4 and 10 and the text for further details.

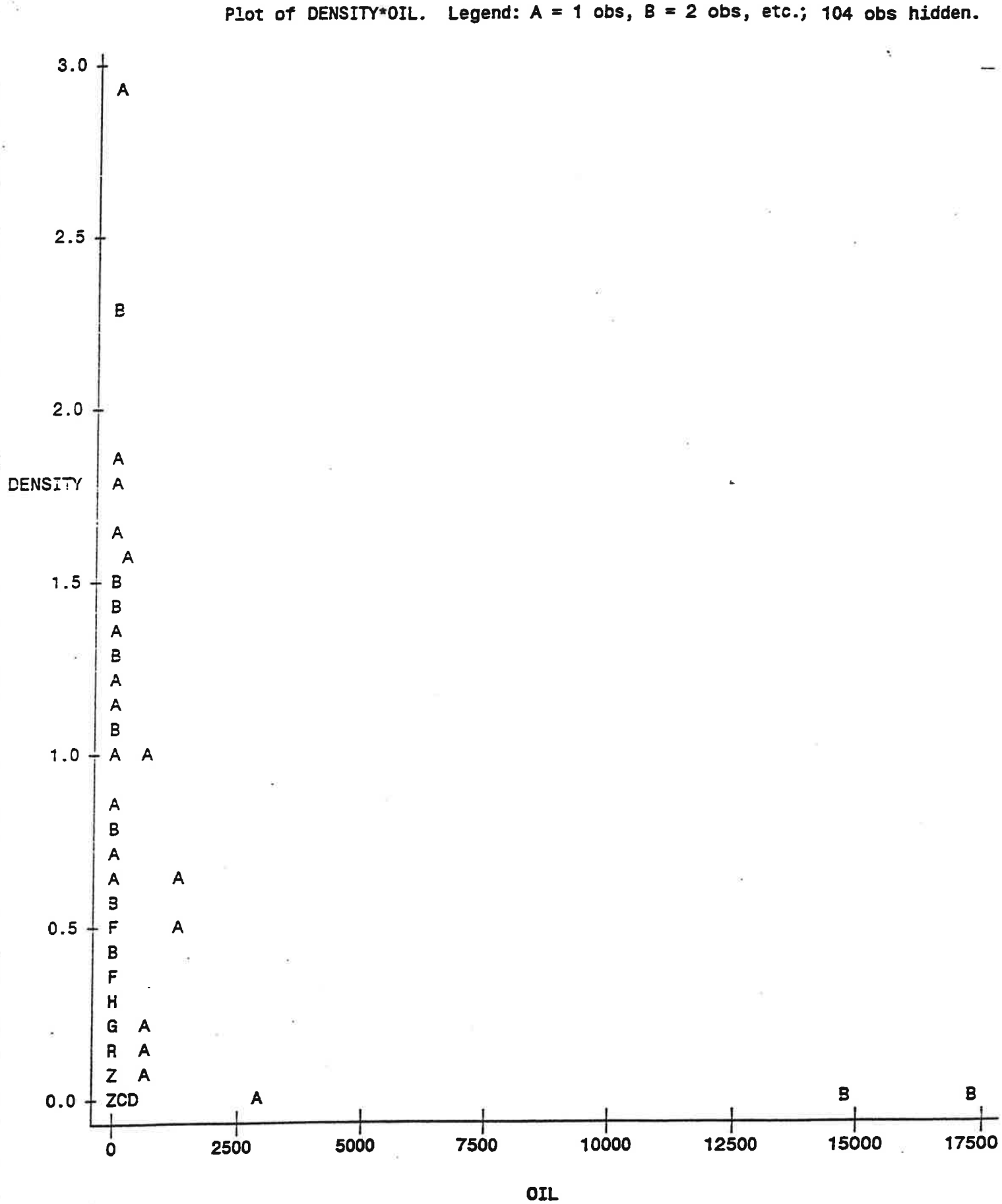


Figure ES-5. Log-transformed *Anchoa* spp. densities (no./m$^3$) from impact stations associated with the LOOP offshore terminal (i.e., stations 53 and 55) plotted against offshore LOOP - related oil spill data (gallons).

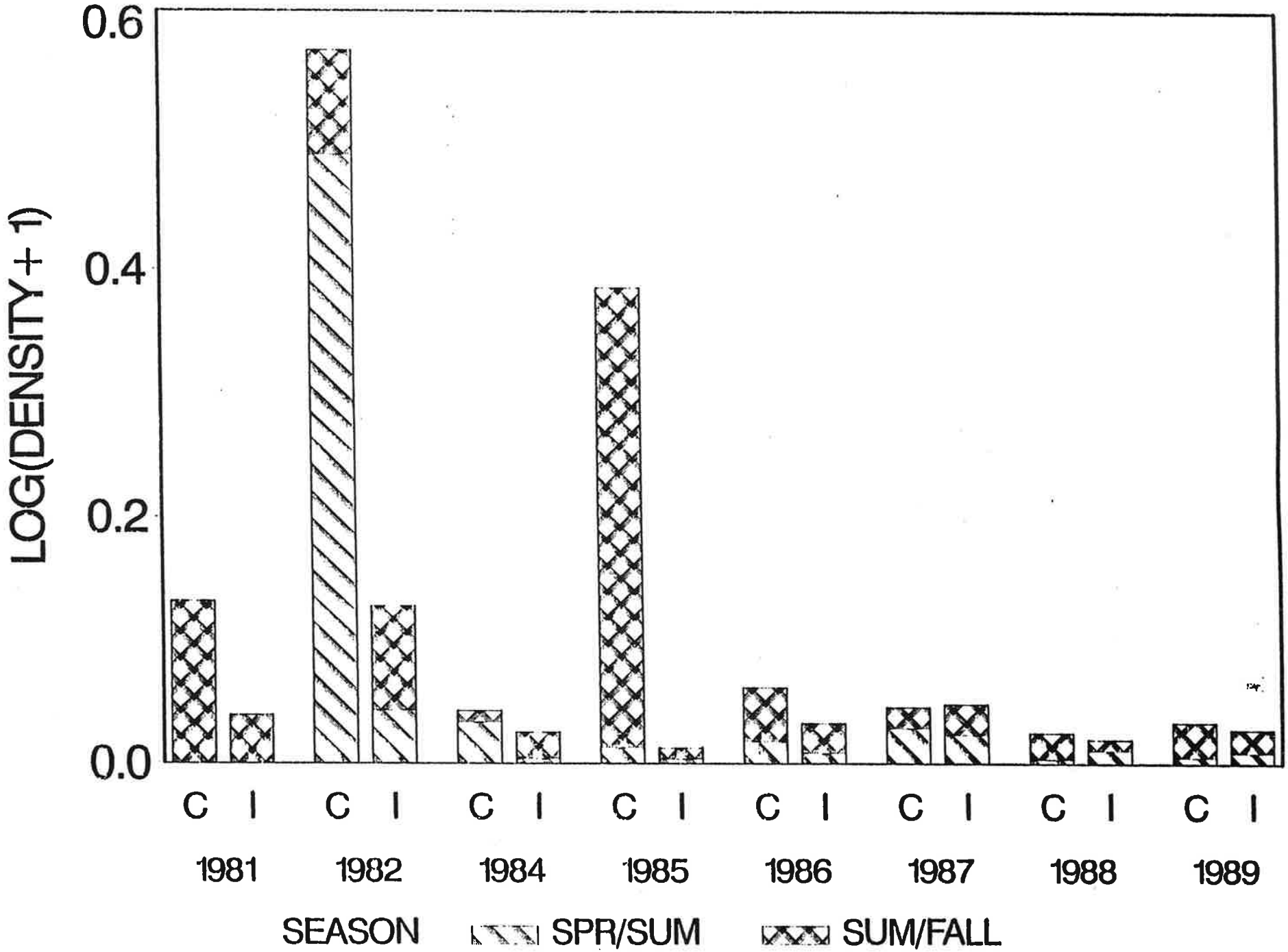


Figure ES-6. Log-transformed *Chloroscombrus chrysurus* mean annual densities (no./m$^3$) by season for control and impact stations from the CI offshore LOOP terminal oil impact analysis. The time period tested was from August 1981 to September 1989. Note the absence of 1983 data. See Tables 4 and 11 for further details.

Table ES-1. Summary of statistical analyses used to investigate potential environmental impacts resulting from LOOP related activities. Listed are the type of statistical model used, type of impact tested for, the time period defined within each test, the LDWF zooplankton/ichthyoplankton stations used and divided into impact and controls, and the taxonomic groupings used. BACI = Before-After, Control-Impact statistical design. DACI = During-After, Control-Impact statistical design. See Table 1 for definitions of HL, BO, BH, BS, and BHH station gears. N = Total number of stations available for analysis; + sign indicates a positive station (i.e., a station at which that organism was collected).

| | | Time Period | | | Stations Used | | |
|---|---|---|---|---|---|---|---|
| Statistical Model | Type of Impacts | Before | During | After | Control | Impact | Taxonomic Groupings |
| BACI, ANOVA Mixed Model | Inshore, Long-term Combined Impacts - with oil data with season (main effect); HL stations only; See Table 5 for statistical results. | 2/78-2/79 | | 3/79-12/95 | 7<br>(407)<br>(≈462)<br>11<br>15<br>(≈464)<br>16<br>38<br>(≈463)<br>39 | 1 13<br>6 14<br>8 18<br>9 32<br>10 33<br>12 37<br>(40) 41 | Zooplankton biomass (displacement vol.); N = 2070<br>*Penaeus aztecus*; N = 1835 with 106 + sta.'s; excluded 2/78<br>c. Osteichthyes; N = 1727 with 766 + sta.'s; starts 3/78 and no data from 2-4/82 |
| BACI, ANOVA Mixed Model | Inshore, Long-term Construction Impacts - without oil or brine data with season (main effect) for pipeline & Clovelly; maximizing longevity of stations while minimizing variability of extraneous transient stations; HL stations only; See Table 6. | 2/78-2/79 | | 3/79-8/85 | 7<br>(407)<br>(≈462)<br>15<br>(≈464)<br>16 | 1<br>12<br>13<br>14<br>18 | Zooplankton biomass (settled vol.); N = 613<br>*Penaeus aztecus*; No fall (only 1 + sta.) and excluded sta. 16 (no catch); N = 412 with 24 + sta.'s<br>c. Osteichthyes; N = 581 with 301 + sta.'s |
| BACI, ANOVA Mixed Model | Inshore Construction Impacts Reduced Time Interval - without oil or brine data with season (main effect) for pipeline & Clovelly; maximizing more detailed zooplankton data set early in study; HL stations only; See Table 7. | 2/78-2/79 | | 3/79-3/83 | 7<br>(407)<br>(≈462)<br>15<br>(≈464)<br>16 | 1 13<br>6 14<br>8 18<br>9 41<br>10<br>12 | *Acartia* spp.; excluded stations where no copepods were identified; excluded nauplii; N = 550 with 489 + sta.'s<br>Copepoda; minus *Acartia* spp.; N = 550 with 513 + sta.'s<br>Decapoda; includes *Penaeus aztecus*; N = 423 with 264 + sta.'s<br>Polychaeta; N = 543 with 200 + sta.'s<br>Gastropoda; N = 543 with 184 + sta.'s |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| DACI, ANOVA Mixed Model | Inshore, Long-term Construction Impacts -no pre-impact data; without oil or brine data with season (main effect) for pipeline & Clovelly; maximizing longevity of stations especially those which started later while minimizing variability of extraneous stations; HL stations only; See Table 8. | | 3/79-3/81 | 4/81-8/85 | 7<br>15<br>16<br>38<br>(≈463) | 1 18<br>12 37<br>13 41<br>14 | Zooplankton biomass (settled vol.); N = 674<br>*Penaeus aztecus*; no fall (only 2 + sta.'s); N = 640 with 41 + sta.'s<br>c. Osteichthys; data gap 2/80-4/80; N = 642 with 355 + sta.'s |
| DACI, ANOVA Mixed Model | Long-term Offshore Brine Disposal - Diffuser - with and without brine data with season (main effect); contains gap in detailed zooplankton data (2/84-7/86); maximizes longevity of appropriate stations; OM stations only; See Table 9. | | 5/80-11/83 | 12/83-12/95 | 36<br>(475) | 21<br>22<br>(422)<br>35/535 | Zooplankton biomass (displacement vol.); N = 666<br>*Penaeus aztecus*; N = 470 with 194 + sta.'s<br>*Callinectes sapidus* (megalopa); N = 462 with 253 + sta.'s; During starts 1/81 with first occurrence<br>*C. similis* (megalopa); N = 460 with 253 + sta.'s; During starts 1/81 with first occurrence<br>*Brevoortia patronus* (includes all *Brevoortia* spp. larvae; N = 308 with 209 + sta.'s; just two seasons putting Apr. into Winter and Sept. into Fall; During starts 12/80<br>*Anchoa* spp. (includes Engraulidae, *A. hepsetus* and *A. mitchilli*); N = 441 with 275 + sta.'s; During starts 2/81<br>Myctophidae (includes *Diaphus* spp., *Lampanyctus* spp. and *Hygophum* spp.) N = 238 with 82 + sta.'s but low abundance; only Winter (months 11, 12 + 1) and Spring (months 2, 3 + 4); During starts 1/81 with first occurrence<br>*Chloroscombrus chrysurus*; N = 322 with 123 + sta.'s; excludes Winter; During starts 5/81 with first occurrence<br>*Cynoscion arenarius*; N = 208 with 102 + sta.'s; excluded Winter - 10 observations and Fall - 9 observations; During starts 4/82 with first occurrence<br>*Sciaenops ocellatus*; N = 92 with 71 + sta.'s; instead of by Season model run on Month = 8, 9 and 10; During starts 8/81; due to small sample sizes model is weak<br>Blennidae (includes *Hypsobennius hentzi*, *Ophioblennius* spp., and *Scartella cristata*); N = 437 with 194 + sta.'s; During starts 3/81 with first occurrence<br>Gobiidae (includes *Gobionellus hastatus* now renamed *G. oceanicus*); N = 444 with 84 + sta.'s but low abundances; During starts 1/81 with first occurrence<br>Scombridae; N = 420 with 43 + sta.'s but low abundances; During starts 7/81 with first occurrence<br>*Peprilus* spp. [includes *P. alepidotus* (≈*P. paru*), *P. burti*, and Stomateidae]; N = 429 with 52 + sta.'s but low abundances; During starts 4/81 with first occurrence<br>Bothidae; N = 442 with 72 + sta.'s but low abundances; during starts 1/81 with first occurrence |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| DACI,<br>ANOVA<br>Mixed<br>Model | Reduced Long-term Offshore Brine Disposal - Diffuser - with and without brine data with season (main effect); insufficient detailed zooplankton data due to data gap (2/84-7/86); maximizing longevity of stations while minimizing variability of extraneous transient stations and of a long After time period; HL stations only; See Table 10. | | 5/80-11/83 | 12/83-7/86 | 36<br>(475) | 21<br>22<br>(422)<br>35/535 | Zooplankton biomass (settled vol.); N = 263 |
| CI<br>ANOVA<br>Mixed<br>Model | Long-term Offshore LOOP Terminal Oil Impact-with LOOP offshore terminal oil data (which ends 12/94) as a covariate and year and season as main effects; no pre-impact and no after impact; maximizing longevity of stations while minimizing variability of extraneous transient stations; OM stations only;<br>** data start and end dates used within the indiv. taxonomic analyses varies - see Taxonomic Groupings column; see Table 11. | | 5/81*-<br>12/94*<br>(see Type of Impact column notes) | | 53<br>(481)<br>55<br>486<br>708 | 52<br>(482)<br>54<br>(479)<br>704<br>706 | Zooplankton biomass (displacement vol.); N = 642<br>*Penaeus aztecus* (postlarvae); data outside of 8/82 to 2/90 time period too sparse to analyze; N = 322 with 95 + sta.'s<br>*Callinectes sapidus* (megalopa); no 1983 data; data analyzed from 5/81 to 12/89; N = 302 with 113 + sta.'s<br>*C. similis* (megalopa); data analyzed from 5/81 to 2/90; N = 344 with 168 + sta.'s<br>*Portunus* spp. (megalopa); data analyzed from 4/82 to 12/89; N = 318 with 149 + sta.'s<br>*Brevoortia patronus* (includes *B. gunteri*); no Spring and Summer seasons; data analyzed from 10/82 to 2/90; N = 158 with 134 + sta.'s<br>*Anchoa* spp. (includes Engralidae, *A. hepsetus* and *A. mitchilli*); data analyzed from 6/81 to 9/89; no Fall; N = 247 with 154 + sta.'s<br>Myctophidae (includes *Centrobranchus nigrocellatus, Diagenichthys atlanticus, Notoscopelus resplendens, Diaphus* spp., *Gonichthys* spp., *Hygophum* spp., *Lampanyctus* spp., and *Myctophum* spp.); data analyzed from 5/82 to 2/90; no Summer; N = 244 with 109 + sta.'s<br>*Chloroscombrus chrysurus*; no 1983 data; just two seasons - Spr./Sum. = months 5, 6 and 7 and Sum./Fall = months 8, 9 and 10; N = 145 with 71 + sta.'s<br>*Cynoscion arenarius*; no Fall data; data analyzed from 4/82 to 9/89; N = 239 with 64 + sta.'s; low abundance<br>Blennidae (includes *Hypoblennius* spp. and *Ophioblennius* spp.); data analyzed from 8/81 to 6/89; N = 310 with 179 + sta.'s<br>Scombridae; no Winter; just two seasons - Spr./Sum = months 4, 5 and 6 and Sum./Fall = months 7, 8, 9 and 10; N = 190 with 74 + sta.'s<br>*Peprilus* spp. [includes *P. alepidotus* (= *P. paru*), *P. burti* and Stomateidae]; no Summer; data analyzed from 11/81 to 3/88; N = 194 with 71 + sta.'s<br>Bothidae; data analyzed from 5/81 to 6/89; N = 315 with 70 + sta.'s; low abundance<br>*Symphurus* spp. (includes *S. plagiusa* and Cynoglossidae); no Winter; data analyzed from 5/81 to 9/89; N = 248 with 76 + sta.'s; low abundance |

Table ES-2. Summary of parameters tested and their specific environmental impact test results which are given within the parentheses as actual P values for main effects, covariates or interactions versus the Bonferroni adjusted alpha values for that family of multiple tests. Also provided are test interpretation codes: Significant (S), Marginally Significant (MS), and Non-Significant (NS) with a probable explanation of significant observed differences, i.e., Direct Loop Impact (DLI), Indirect LOOP Impact (ILI), or Non-LOOP Impact (NLI). Also presented is a probable explanation of why marginally significant or non-significant responses were found, i.e., Parameter Insensitive to LOOP operations (PI), Parameter Sensitive But Variability too high to detect significant differences with the sampling design used (PSBV), or Parameter Sensitive to LOOP operations, but LOOP operations Not Implicated (PSNI). The reader is referred to Appendix Tables A-2 to A-7 for a listing of all biological parameters used (zooplankton and ichthyoplankton monthly mean densities across all years with number of positive sampling stations and standard deviations needed to calculate 95% confidence limits and/or coefficients of variation). See Tables 5-11 for test results.

| Parameter Tested | Specific Test Results | Sig. Code | Prob. Explanation for Sig. or Marginal Sig. | Prob. Reason for Marginal Sig. or Non-Sig. |
|---|---|---|---|---|
| Zooplankton biomass estimate (settled +/or displacement vol. - ml/m$^3$) | BACI Inshore Combined Impact on pipeline and Clovelly with oil as a covariate (2/78-12/95) (P = 0.0983 vs. 0.0167) | MS | DLI | PSBV |
| | BACI Inshore Construction (2/78 - 8/85) | NS | | PSBV |
| | DACI Inshore Construction (3/79 - 8/85) | | | |
| | • Seasonal effect ( P = 0.0005 vs. 0.0167) | S | NLI | |
| | • During-After, Control-Impact interaction (P = 0.0428 vs. 0.0100) | MS | DLI | PSBV |
| | DACI Offshore Diffuser with brine as a covariate OM data only (5/80 - 12/95) | NS | | PSBV |
| | • Model rerun with no brine data - During-After interaction (P = 0.0303 vs. 0.0036) | MS | NLI | PSBV |
| | DACI Offshore Diffuser with brine as covariate HL data only (5/80 - 7/86) | NS | | PSBV |
| | • No brine data - Seasonal effect (P = 0.0001) | S | NLI | |
| | • No brine data - During-After effect (P = 0.0510) | MS | NLI | PSBV |
| | • No brine data - During-After Seasonal interaction (P = 0.0029) | S | NLI | |
| | • No brine data - During-After, Control-Impact interaction (P = 0.0566) | MS | ILI | PSBV |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (5/81 - 12/94) | NS | | PSBV |
| | • Seasonal effect (P = 0.0162 vs. 0.0033) | MS | NLI | PSNI |
| | • Year effect (P = 0.0078 vs. 0.0033) | MS | NLI | PSNI |
| | • Year - Season interaction (P = 0.0003 vs. 0.0033) | S | NLI | |
| *Penaeus aztecus* | BACI Inshore Combined Impact with oil as a covariate (2/78-12/95) | NS | | PSBV |
| | BACI Inshore Construction (2/78 - 8/85) | NS | | PSBV |
| | • Control-Impact Seasonal interaction (P = 0.0543 vs. 0.0167) | MS | NLI | PSBV |
| | DACI Inshore Construction (3/79 - 8/85) | NS | | PSBV |
| | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PSBV |
| | • No brine data - Seasonal effect (P = 0.0027 vs. 0.0036) | MS | NLI | PSNI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (6/82 - 2/90) | NS | | PSBV |
| | • Season effect (P = 0.0001 vs 0.0033) | S | NLI | |
| | • Year effect ( P = 0.0316 vs 0.0033) | MS | NLI | PSNI |
| | • Year Season interaction (P = 0.0001 vs 0.0033) | S | NLI | |

| Parameter Tested | Specific Test Results | Sig. Code | Prob. Explanation for Sig. or Marginal Sig. | Prob. Reason for Marginal Sig. or Non-Sig. |
|---|---|---|---|---|
| *Callinectes sapidus* | BACI Inshore Combined Impact with oil as a covariate (2/78-12/95) | NS | | PSBV |
| | • No brine data - Seasonal effect (P = 0.0001 vs. 0.0036) | S | NLI | |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (5/81 to 12/89 but no 1983 data) | NS | | PSBV |
| | • Seasonal effect (P = 0.0002 vs. 0.0033) | S | NLI | |
| | • Control-Impact Seasonal interaction (P = 0.0005 vs. 0.0033) | S | NLI | |
| | • Year effect (P = 0.0001 vs. 0.0003) | S | NLI | |
| | • Control-Impact Yearly interaction (P = 0.0001 vs. 0.0033) | S | NLI | |
| | • Year Season interaction (P = 0.0001 vs. 0.0033) | S | NLI | |
| | • Control-Impact, Year Season interaction (P = 0.0001 vs. 0.0033) | S | NLI | |
| *C. similis* | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PSBV |
| | • No brine data - During-After effect (P = 0.0572 vs. 0.0036) | MS | NLI | PSBV |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (5/81 to 2/90) | NS | | PSBV |
| | • Seasonal effect (P = 0.0683 vs. 0.0033) | MS | NLI | PSNI |
| | • Year effect (P = 0.0333 vs. 0.0033) | MS | NLI | PSNI |
| | • Year Season interaction (P = 0.0001 vs. 0.0033) | S | NLI | |
| *Acartia* spp. | BACI Inshore Construction Impact (2/78 - 3/83) | NS | | PSBV |
| | • Seasonal effect ( P = 0.0001 vs. 0.0100) | S | NLI | |
| | • Before-After Seasonal interaction (P= = 0.0222 vs. 0.0100) | MS | NLI | PSNI |
| Copepoda | BACI Inshore Construction Impact (2/78 - 3/83) | NS | | PSBV |
| | • Seasonal effect (P = 0.0637 vs. 0.0100) | MS | NLI | PSBV |
| | • Before-After Seasonal interaction (P = 0.0027 vs. 0.0100) | S | NLI | |
| | • Control-Impact Seasonal interaction (P = 0.0013 vs. 0.0100) | S | NLI | |
| | • Before-After, Control-Impact Seasonal interaction (P = 0.0037 vs. 0.0100) | MS | NLI | PSNI |
| Decapoda | BACI Inshore Construction Impact (2/78 - 3/83) | NS | | PSBV |
| | • Seasonal effect (P = 0.0001 vs. 0.0100) | S | NLI | |
| | • Before-After Seasonal interaction (P = 0.0559 vs. 0.0100) | MS | NLI | PSNI |
| Polychaeta | BACI Inshore Construction Impact (2/78 - 3/83) | NS | | PSBV |
| | • Seasonal effect (P = 0.0001 vs. 0.0100) | S | NLI | PSBV |
| | • Before-After Seasonal interaction (P = 0.0059 vs. 0.0100) | MS | NLI | PSBV |
| Gastropoda | BACI Inshore Construction Impact (2/78 - 3/83) | NS | | PSBV |
| | • Seasonal effect (P = 0.0001 vs. 0.0100) | S | NLI | |

| Parameter Tested | Specific Test Results | Sig. Code | Prob. Explanation for Sig. or Marginal Sig. | Prob. Reason for Marginal Sig. or Non-Sig. |
|---|---|---|---|---|
| c. Osteichthyes | BACI Inshore Combined Impact with oil as covariate (2/78-12/95) | NS | | PSBV |
| | • No oil data - Control-Impact interaction (P = 0.0861 vs. 0.0167) | MS | DLI | PSBV |
| | BACI Inshore Construction Impact (2/78 - 8/85) | NS | | PSBV |
| | DACI Inshore Construction (3/79 - 8/85) | | | |
| | • Seasonal effect (P = 0.0033 vs. 0.0100) | S | NLI | |
| | • During-After Seasonal interaction (P = 0.0046 vs. 0.0100) | S | NLI | |
| | • Control-Impact Seasonal interaction (P = 0.0962 vs. 0.0100) | MS | NLI | PSBV |
| *Brevoortia patronus* | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PSBV |
| | • No brine data | NS | | PSBV |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (10/82 to 2/90) | NS | | PSBV |
| | • Seasonal effect (P = 0.0248 vs. 0.0033) | MS | NLI | PSBV |
| | • Year effect (P = 0.0849 vs. 0.0033) | MS | NLI | PSBV |
| | • Year Season interaction (P = 0.0656 vs. 0.0033) | MS | NLI | PSBV |
| *Anchoa* spp. | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PSBV |
| | • No brine data - Seasonal effect (P = 0.0001 vs. 0.0036) | S | NLI | |
| | • No brine data - During-After Seasonal interaction (P = 0.0755 vs. 0.0036) | MS | NLI | PSBV |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (6/81 to 9/89) (P = 0.0991 vs. 0.0033) | MS | DLI | PSBV |
| | • Seasonal effect (P = 0.0023 vs. 0.0033) | S | NLI | |
| | • Year effect (P = 0.0023 vs. 0.0033) | S | NLI | |
| Myctophidae | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data | NS | | PI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (5/82 - 2/90) | NS | | PSBV |
| | • Seasonal effect (P = 0.0004 vs. 0.0033) | S | NLI | |
| | • Year effect (P = 0.0247 vs. 0.0033) | MS | NLI | PSBV |
| | • Year Season interaction (P = 0.0962 vs. 0.0033) | MS | NLI | PSBV |
| *Sciaenops ocellatus* | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data | NS | | PI |
| *Chloroscombrus chrysurus* | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PSBV |
| | • No brine data - Seasonal effect (P = 0.0001 vs. 0.0036) | S | NLI | |
| | • No brine data - During-After Seasonal interaction (P = 0.0745 vs. 0.0036) | MS | NLI | PSNI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (8/81 to 9/89 but no 1983 data) | NS | | PSBV |
| | • Year effect (P = 0.0565 vs. 0.0033) | MS | NLI | PSBV |
| | • Year Season interaction (P = 0.0770 vs. 0.0033) | MS | NLI | PSBV |
| | • Control-Impact, Year Season interaction (P = 0.0271 vs. 0.0033) | MS | DLI | PSBV |
| *Cynoscion arenarius* | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PSBV |
| | • No brine data - Seasonal effect (P = 0.0071 vs. 0.0036) | MS | NLI | PSNI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (4/82 to 9/89) | NS | | PSBV |

| Parameter Tested | Specific Test Results | Sig. Code | Prob. Explanation for Sig. or Marginal Sig. | Prob. Reason for Marginal Sig. or Non-Sig. |
|---|---|---|---|---|
| Blennidae | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data - Seasonal effect (P = 0.0117 vs. 0.0036) | MS | NLI | PI |
| | • No brine data - During-After effect (P = 0.0713 vs. 0.0036) | MS | NLI | PSBV |
| | • No brine data - During-After Seasonal interaction (P = 0.0809 vs. 0.0036) | MS | NLI | PSBV |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (8/81 to 6/89) | NS | | PSBV |
| | • Seasonal effect (P = 0.0044 vs. 0.0033) | MS | NLI | PSBV |
| | • Year Season interaction (P = 0.0247 vs. 0.0033) | MS | NLI | PSBV |
| Gobiidae | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data - During-After Seasonal interaction (P = 0.0333 vs. 0.0036) | MS | NLI | PI |
| Scombridae | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data - Seasonal effect (P = 0.0194 vs. 0.0036) | MS | NLI | PI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (8/81 to 9/89) | NS | | PSBV |
| | • Year effect (P = 0.0111 vs. 0.0033) | MS | NLI | PSBV |
| *Peprilus* spp. | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data | NS | | PI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (11/81 to 3/88) | NS | | PSBV |
| Bothidae | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data | NS | | PI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (5/81 to 6/89) | NS | | PI |
| *Portunus* spp. | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (4/82 to 12/89) | NS | | PSBV |
| | • Seasonal effect (P = 0.0066 vs. 0.033) | MS | NLI | PSBV |
| | • Year effect (P = 0.0018 vs. 0.0033) | S | NLI | |
| | • Year Season interaction (P = 0.0007 vs. 0.0033) | S | NLI | |
| *Symphurus* spp. | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (5/81 to 9/89) | NS | | PI |

addition, plankton are often useful as "indicators" of water quality in an area as a result of known physical and chemical tolerances and vulnerability to many natural and anthropogenic disturbances (Bratkovich 1988). Furthermore, distinct plankton assemblages have been recognized as characteristic communities associated with specific water-mass types (Robinson et al. 1986 and references therein) or environments.

Virtually all of the commercially- and recreationally-important marine fisheries resources in the northern Gulf of Mexico are "nearshore-dependent" or "inshore-dependent" (Gunter 1967; 1980), which means that some portion of their life cycle is directly or indirectly linked to inshore ecosystems for reproduction (as spawning or nursery areas), migration or feeding. Given a sufficient number of spawning adults, the potential population size of these species is controlled most strongly by conditions affecting reproduction and nursery areas (NMFS 1992). This is because most marine fish and shellfish die during their larval and early juvenile stages (approx. 99.99%). Therefore, the ultimate population size of most marine finfish species is determined largely by surviving the "critical period" (Lasker 1981) experienced during their first year of life within their nursery areas.

Information on distributional and temporal patterns of holoplankton and the planktonic stages of shellfish and finfish is important for a better understanding of ecological/trophic dynamics and for the future management of Louisiana's valuable fisheries. Zooplankton research in the shelf-waters of northcentral Gulf of Mexico has been reviewed by Hopkins (1973) and Iverson and Hopkins (1981). However, current knowledge of how these biological resources relate to dominant physical/chemical parameters at large temporal (i.e., years) or large spatial scales, is limited. With the notable exception of Arnold (1958) and possibly Czapala et al. (1991), most zooplankton studies have been short-lived and site-specific or conducted within state waters (Davis 1950; King 1950; Cuzon du Rest 1963; Gillespie 1971; Perry and Christmas 1973; Angelovic et al. 1976; Park et al. 1976; Park 1977, 1979; Barrett et al. 1978; Marum 1979; Minello 1980; Park and Minello 1980; Steen and Gunter 1980; Vecchione et al. 1982, 1983; Wolff et al. 1984; Dagg 1988; Rogers et al. 1993). A similar argument can be made for most ichthyoplankton studies (Finucane 1976; Finucane et al. 1977, 1979a, 1979b; Wolff et al. 1984, 1985; McGowan 1985; Shaw et al.

1985a, 1985b, 1988; Cowan and Shaw 1988, 1991; Govoni et al. 1989; Shaw and Drullinger 1990a; Grimes and Finucane 1991; Lang et al. 1994). Geographical exceptions include Sogard et al. (1987) and Al-Yamani (1988), and temporal exceptions include those analyses utilizing gulfwide NOAA/NMFS Southeast Area Monitoring and Assessment Program (SEAMAP) data, e.g., Richards et al. (1984), Kelley et al. (1986, 1993), Eldridge (1988), Shaw and Drullinger (1990b), Ditty and Shaw (1992, 1993, 1995), and Ditty et al. (1994a, 1994b, 1994c) and data from the Louisiana-Texas shelf (Shaw et al. 1997).

In addition to the LDWF quarterly and annual progress reports, publications to date that have utilized LOOP environmental monitoring data on zooplankton and ichthyoplankton include Ditty (1986, 1991), Ditty et al. (1988), and Power and Zieske (1989). In addition, LDWF has reported LOOP project data on zooplankton and ichthyoplankton collected at inshore stations from March 1978 to February 1982 and at offshore stations through November 1982 (Ditty et al. 1987). Their construction and brine monitoring field sampling data indicated a high degree of spatial and temporal variability for copepods, *Penaeus* spp. (shrimp) postlarvae, *Callinectes sapidus* (blue crab) megalopae, and fish larvae. A similar high degree of temporal, spatial and vertical variability was subsequently seen within LOOP data set analyses involving comparisons of zooplankton biomass (ml/m$^3$) monthly estimates from 1993 with long-term (1983-1992) monthly means with 95% confidence intervals (C.I.) (Kasprzak et al. 1994). In a more detailed analysis, 1995 zooplankton biomass, larval fish and commercially-important decapod postlarvae and megalopae densities (no./100m$^3$) were compared to long-term (1982-1994) monthly means (with 95% C.I.) (Kasprzak et al. 1996). Seasonality, species composition, and spatial and vertical distributions of the most abundant larval fish species and families, e.g., *Brevoortia patronus* (gulf menhaden), *Chloroscombrus chrysurus* (Atlantic bumper), *Leiostomus xanthurus* (spot), *Cynoscion arenarius* (sand seatrout), f. Engraulidae (anchovies), f. Synodontidae (lizardfishes), f. Blenniidae (combtooth blennies), and f. Gobiidae (gobies), and a number of commercially-important decapod crustacean species, e.g., *Penaeus aztecus* (brown shrimp) postlarvae, *Callinectes sapidus*, and *C. similus* (lesser blue crab), and *Portunus* spp. megalopae were also reported. The selection criteria for the zooplankton taxonomic categories listed above were based on economic value

(i.e., commercial and recreational importance), available zooplankton identification expertise, time constraints, and availability of funding for sample processing.

# METHODS

## Field Sampling Procedures

Primary references used to determine appropriate sampling methodologies for the project, standard zooplankton field sampling devices, and procedures for sample preservation, curation, and laboratory analysis included Tranter (1968), Kramer et al. (1972), Steedman (1976), Smith and Richardson (1977), Jossi and Marak (1983), and Omori and Ikeda (1984).

Over the course of the zooplankton and ichthyoplankton field sampling program (February 1978 to December 1995), a total of 97 plankton stations were sampled at one time or another at environments ranging from freshwater to mid-continental shelf (Table 1). Four (4) sampling gears and six (6) different sampling protocols were employed over the duration of the study. To examine the potential impacts of floating oil, surface tows were taken at inshore and offshore stations. In deeper offshore waters, bongo nets were used to sample zooplankton and ichthyoplankton occupying various divisions of the water column where effects of aged and dispersed oil would most likely occur.

Half meter diameter, conical plankton nets (Sea-Gear Corp.) were towed at the surface for one minute at a speed of 1 m/s (2 knots) at all inland (freshwater and estuarine) stations. Prior to August 1987 a mechanical, rotor-type flowmeter (General Oceanics Model 2030R) was attached to the mouth of the nets to measure volume of water filtered. Thereafter an external gear-train, 4-dial-counter flowmeter (Kahl Scientific Co. Model 005WA200) was employed. At the freshwater stations (i.e., 24-30; Figure 1) net mesh size was 0.80 mm. This sampling gear/protocol will be designated hereafter as Half-meter Small mesh or HS. At all other inland stations the 0.5 m net mesh size was 0.153 mm (Half-meter Large mesh or HL). Freshwater stations 28 to 30 were briefly sampled with both net mesh sizes. One inland station, 37 in Bayou Lafourche, was also sampled with a one-meter diameter plankton net.

All One-Meter (OM) nets had 0.363 - mm mesh and were towed horizontally at the surface for 3-5 minutes depending upon plankton abundance. Marine stations right along the coast (depth < 4 m) utilized the HL methodology, while most "Near-Offshore" stations (4 m < depth < 13 m) and "Far-Offshore" stations (14 m $\leq$ depth $\leq$ 37 m) were sampled utilizing both HL and OM methodologies for at least some time period. Exceptions to this generality include: (1) Near-Offshore stations 4, 44, 422, and 435 - HL sampling only; (2) Near-Offshore stations 467 to 476 and FO stations 477 to 482 and 484 to 486 - OM sampling only; and (3) bongo net sampling stations sometimes referred to as the "Plankton Transect Stations".

Four (4) bongo net methodologies were used during the study. All employed 60-cm diameter, 0.363 - mm mesh nets attached to an opening and closing, paired net frame (Tareq and Co., Inc. - BNF-1 model) fitted with a flowmeter and towed at 1 m/s for 3-5 minutes depending upon plankton abundance and/or the depth of the water column. General Oceanics double trip mechanisms (Model 1000-DT) were used to open and close the hinged net frame at starting and ending depths.

One of the methodologies or sampling protocols involved stepped-oblique bongo tows (referred to hereafter as BO = Bongo Oblique). The BO tows were taken through the whole water column (from near-bottom to the surface) with a single, paired net bongo frame which was deployed closed, opened at the surface, lowered in stepped increments to near the bottom and then retrieved smoothly to the surface.

Another methodology involved two sets of bongo net frames and double trip mechanisms which were used to simultaneously sample the upper and lower portions of the water column in an oblique fashion (from mid-depth to surface and from one meter off the bottom to mid-depth). The net frames were deployed closed, opened at depth (surface and mid-depth), stepped down in increments to mid-depth and near-bottom, then retrieved to their starting depths and closed. This methodology will be referred to as BH (Bongo Half oblique).

A third methodology involved three bongo frames with double trip mechanisms being simultaneously towed horizontally. These nets were opened and closed at the surface, mid-depth and near-bottom and are referred to as BS (Bongo Stratified). The fourth sampling protocol consisted of two bongo net frames with double trip mechanisms which were opened and closed at the near surface and near bottom and simultaneously towed horizontally, designated BHH (Bongo Half Horizontal).

Bongo net stations, or Plankton Transect Stations, were phased in between 1981 and 1986 and included Near-Offshore stations: (a.) 500, 501, 505 and 506 - BS sampling only; (b.) 701 - BO sampling only; (c.) 507 - BS and BO; (d.) 502 - BS, BO, and OM; and (e.) 535/35 - BS, BO, OM, and HL sampling, and Far-Offshore stations: (a.) 704, 711, 713, 788 and 798 - BH and OM; and (b.) 706 and 708 - BHH, BH and OM sampling.

Zooplankton and ichthyoplankton sampling was conducted monthly at most stations with quarterly sampling at stations 23 - 30, 50-54 (from 6/80 to 12/81), 407, 419, 422, 434, 435 and 460 - 486 (Figure 1). Only seven stations were sampled continuously from early in the study, February to July 1978, to near its completion - Stations 5, 7 [12 (when combined with station 40) and 13 - both ended in May 1994], 14, 15, and 18 - all HL stations (Table 2). If you consider locations that were occupied continuously but sampling with one gear or methodology ended and was replaced by one or more different methodologies, then two additional stations (21 and 22) are added to this list. In 1979 station 34 (HL) was added to the list of continuously sampled stations. In 1980 stations 37 and 38 (HL) and 21, 22, 35/535, 36 and 52 (all OM) were initiated, while in 1982 station 55 (OM) was added. In 1984 the first of the continuously sampled bongo net stations were added - 35/535 (BO), 502 (BO), 704 (BH), 706 (BH), and 708 (BH). In 1985, station 39 (HL) and in 1986 stations 37 (OM), 502 (OM), 706 (OM), and 708 (OM) were added. In 1987, station 704 (OM) was the last station to be continuously sampled thereafter.

For all of the above mentioned stations, however, the actual zooplankton and ichthyoplankton data streams (i.e., time lines when the samples were sorted, identified and entered into the computerized data base) are often quite different from a station time line that

would be generated by a particular sampling station being occupied or when a plankton sample may have been collected out in the field but subsequently not picked, sorted, identified or entered into the data base back in the laboratory.

## Sample Preservation

Large jellyfish, sargassum, and other large material collected in a tow were noted, separated from the catch, rinsed to rid them of adhering plankton organisms, then discarded. The remaining sample was passed through plankton netting of the same mesh as that of the collecting net, then transferred to collecting jars. Care was taken to not fill sample jars more than 30 percent full with collected sample to avoid spoilage or incomplete preservation.

Samples were preserved in the field with full-strength formalin buffered with sodium phosphate added to filtered ambient water to yield a final concentration of 10-15% (Steedman 1976). The sample jars were transported to the lab in protective carriers and kept out of direct light sources by storing in a cool, well-ventilated area to prevent fading of pigments and discoloration of zooplankton specimens. In the laboratory, samples were changed over to a fresh solution of 5-10% buffered formalin.

## Hydrography

At inshore stations conductivity, salinity and temperature were measured with a Beckman RS-5 inductive salinometer or a Hydrolab DataSonde II (1990-1995). At offshore stations a vertical profile of the water column for temperature, salinity, conductivity and dissolved oxygen was taken with a Martek Mark VI STD-DO water quality instrument (through 1987) or a Guildline/Rosette CTD-DO/sample bottle array. Dissolved oxygen levels were measured by the azide modification of the Winkler method (APHA 1980, 1985) from Niskin bottle samples collected at surface, middle and bottom depths offshore and on Kemmerer samples collected inshore.

## Laboratory Procedures

Zooplankton settled volume and displacement volume values for whole plankton samples were used to formulate zooplankton biomass ($\approx$ standing stock) estimates. Juvenile fish, larger invertebrates, and conspicuous debris were first noted then removed from the sample. Plankton samples were then placed in graduated cylinders and allowed to settle for 24 hours after which settled volume was recorded (Beers 1976). From January 1982 through July 1987 total plankton biomass estimates were derived from both 24-h settled volume ($\pm$ 0.5 ml) and displacement volume ($\pm$ 0.1 ml; Mercury Immersion Method - Yentsch and Hebard 1957 modified by the use of a vacuum pump to remove interstitial water from the sample). From August 1987 only displacement volume was measured, because it is believed to be a better measurement and often the relationship between settled volume and displacement volume remains relatively constant (George and White 1985). Zooplankton biomass volumes were divided by the volume of water filtered by the plankton net to yield a standardized biomass estimate (ml/m$^3$).

Methodology for obtaining quantitative subsamples for enumeration and identification of the zooplankton component varied during the course of the study by species and species abundance. For samples collected prior to February 1980, a 1.0 ml aliquot was extracted from each zooplankton sample for enumeration and identification of organisms. Samples collected between February and December 1980 were subsampled with a Henson-Stempel pipette. Beginning in January 1981, subsamples were obtained with a Folsom Plankton Splitter (McEwen et al. 1958; Van Guelpen et al. 1982). During the early years of the study, whole samples were completely sorted for postlarval shrimp (*Penaeus* spp.), portunid crab megalopae (e.g., *Callinectes* spp.), and larval fish or subsampled by Folsom splitter when catches were very high. In later years, the entire sample was sorted for penaeid shrimp postlarvae, regardless of sample size and postlarval abundance. For portunid crabs, one-half of the sample was examined when fewer than 50 megalopae were found in a quarter-sample; and the entire sample was sorted when fewer than 100 megalopae were found in a half-sample, for a minimum target number of 200 specimens. Split samples for crabs ranged from 1 to 6 (1/128th). One, half-sample was sorted for ichthyoplankton when fewer than 75 specimens were found in a quarter-sample, and the entire sample was sorted when fewer than 200 fish were found in a half-sample. The subsampling protocol for larval

fish in reality proved to be more conservative than this, given that almost invariably whole or half-samples were sorted. Only in a small number of cases (when larval fish numbers were markedly high) were 1/4th, 1/8th, or 1/16th splits examined. Penaeid shrimp postlarvae, portunid crab megalopae, and larval fish specimens were removed from whole or fractional samples with the aid of binocular dissecting microscopes, then placed into vials for later identification. Shrimp postlarvae and crab megalopae were preserved with 3-5% buffered formalin, and ichthyoplankton specimens were preserved in 70% ethanol.

## Modifications to the Sampling Program

The zooplankton sampling program was revised, subsequent to an analysis by LDWF of project data already obtained, as the environmental program emphasis shifted from monitoring LOOP facility and pipeline construction and brine discharge, to monitoring potential impacts of ongoing operations including oil spill and dispersant use. Additional changes were implemented to streamline the sampling program (decrease field effort and sample processing time), to alleviate the accumulating backlog of unsorted and unidentified plankton collections, and to improve comparability among stations within the LOOP corridor while still providing adequate baseline monitoring data for decision making.

The taking of offshore HL (0.5 m, 0.153 - mm mesh nets) samples was discontinued after July 1986 (however, the last of the offshore HL samples to be worked up and entered onto the computerized data set ended in January-February 1984). The decision to discontinue using both 0.5 and 1.0 meter nets at offshore stations was based upon the results of several ANOVAs conducted by LDWF on 1981 data from stations 21, 22, 35 and 36. Capture efficiencies were analyzed by season for each of the two gear (net) types with respect to certain taxa: *Penaeus* spp., *Callinectes sapidus*, fish larvae, copepods, and total zooplankton. Density estimates by gear type for *Penaeus* spp., *Callinectes sapidus*, and larval fish were not significantly different ($P > 0.05$), while copepods and total zooplankton were significantly more abundant in the HL net ($P \leq 0.0001$). The higher HL copepod and total zooplankton densities were attributed to the likely retention of a greater number of smaller developmental stages within the HL's 0.153 - mm versus the OM's 0.363 - mm net

mesh size. It was also noted that this component of the plankton added a disproportionally large amount of time to the total allocation of effort dedicated to sample processing and identification.

In late 1993 the LOOP Inc. Program Review Committee decided to reduce the loss of timely data caused by the extensive backlog of unsorted or unidentified zooplankton and ichthyoplankton samples that had accumulated over time by endorsing a LDWF proposal to limit sample processing efforts exclusively to seven (7) "target months" (i.e., Jan., Feb., Apr., Jun., Jul., Sep. and Nov.) and to suspend analyses of the plankton data collected at bongo (Plankton Transect) stations. Sampling at the other stations continued on a monthly basis and these collections were archived. This subsampling strategy was based upon the results of statistical analyses conducted by LDWF in 1993 on available LOOP plankton data. These results suggested a gain of relatively minor additional taxonomic information from the OM samples taken at the Plankton Transect (bongo net) Stations when compared to the remaining offshore OM stations. These statistical results were combined with known seasonality data for adult spawning periods and the occurrence of ichthyoplankton, megalopal portunid crabs, and postlarval penaeid shrimp in the plankton to formulate a decision to limit plankton analyses to designated station-gear type combinations and the seven "target months". These months spanned or bracketed peak spawning seasons for penaeid shrimp and portunid crab species, as well as the majority of the ichthyoplankton in the LOOP corridor. While this policy of identifying only specimens collected during the seven months was implemented in 1993 and continued through December 1995, it led to differing station cut-off dates within the computerized data sets because the extent of the existing backlogs differed by station and sampling gear. For example, for HL stations the cut-off date for sample identification of only the "target months" was August or September 1989. For one-meter net (OM) stations 21, 22, 36, 52, and 55, it was August 1987; for station 35/535 - July 1988; station 37 - July 1989; and station 502 - February 1990. For bongo net stations 502, 704, 706 and 708 it was February 1990 and for station 35/535 it was April 1990.

## Zooplankton and Ichthyoplankton Identifications

**Penaeid shrimp and portunid crabs**

Primary references used in the identification of selected decapod crustacean were Felder (1973), Williams (1984), Blanchet (1985/unpubl.), Stuck et al. (unpubl.), and Stuck (unpubl.). Additional life history and seasonality information sources included Cook and Murphy (1971), Gosner (1971), Kurata (unpubl.), and Stuck and Perry (1981).

The decapod crustacean taxa that were identified and enumerated from plankton collections over the duration of the project consisted of the postlarval developmental stage of three penaeid shrimp species: *Penaeus aztecus* (brown shrimp), *P. duorarum* (pink shrimp), and *P. setiferus* (white shrimp), and the megalopal stages of three portunid crab taxa: *Callinectes sapidus* (blue crab), *C. similis* (lesser blue crab), and *Portunus* spp. (swimming crabs - mostly *P. gibbessi*). In addition Copepoda, the postlarval and adult stages of shrimp or shrimp-like species such as *Lucifer* spp., *Acetes americanus,* and *Trachypenaeus* spp. (probably the roughneck shrimp), and the crab species *Ovalipes floridanus* (lady crab) and *Arenaeus cribrarius* (speckled crab) were often recorded as were squid larvae (f. Loliginidae) for most of the study. Often LDWF's Plankton Laboratory personnel identified and enumerated constituent taxa in other major plankton groups (e.g., Doliolida, Larvacae, Cirripedia, Hydrozoa, Siphonophora, Cladocera, Ostracoda, mysids, and Chaetognatha).

**Ichthyoplankton**

Primary references used to facilitate ichthyoplankton identifications were Miller and Jorgenson (1973), Fritzsche (1978), Hardy (1978a, 1978b), Johnson (1978), Jones et al. (1978), Martin and Drewry (1978), Fahay (1983), Moser (1984), and Ditty (unpubl.). Other useful literature on larval fish taxonomy, distributions, and seasonality included Ditty (1984, 1986, 1991), Ditty et al. (1988), and Farooqi (unpubl.). Recognized developmental stages for ichthyoplankton were "yolk-sac", "larvae", "juvenile", and "leptocephalus" (Elopiformes and Anguilliformes) after Fahay (1983).

On an annual basis, the overwhelming majority of the larval and adult marine fish species in the northern Gulf of Mexico belong to five families: Clupeidae (herrings), Engraulidae (anchovies), Sciaenidae (drums), Carangidae (jacks), and Bothidae (lefteyed flounders) (Gillespie 1971; Perry and Christmas 1973; Barrett et al. 1978; Stuck and Perry 1982; Kelly et al. 1983; Richards et al. 1984; Ditty 1986). Consequently, specimens in these families were identified to species when possible, with the exception of the engraulids which presently cannot be reliably identified to species at sizes less than 10-14 mm. Other larval fish specimens that routinely were identified to the lowest possible taxonomic level included the common northern Gulf families Lutjanidae (snappers), Mugilidae (mullets), Scombridae (mackerels), Serranidae (sea basses), and Stromateidae (butterfishes). Two "morphological types" (A and B) were recognized for *Cynoscion arenarius* (Cowan 1985; Ditty 1991) and *Menticirrhus* spp. (kingfishes - Ditty 1991). Serranids were placed in one of four subfamilies: Serraninae, Anthiinae, Epinephelinae, or Grammistinae when identification to species was not accomplished. Ophichthids (snake eels) were divided into two subfamilies: Ophichthinae and Myrophinae. Myctophids (lanternfishes) usually were identified to subfamily: Myctophinae and Lampanyctinae. The remaining ichthyoplankton were identified to family when possible. Extremely small (usually $\leq$ 2 mm yolk-sac or early larvae) or damaged specimens often were identified to order, and in rare cases, assigned to "Class Osteichthyes" (bony fishes) as were virtually all larval fish before 1982. Scientific names that were associated with input values for zooplankton and ichthyoplankton taxonomic codes conform to the 10-digit National Oceanographic Data Center (NODC) codes, Version 6.

## Data Management and QA/QC

Field and laboratory data were entered into the LDWF's central computer and then formatted using VMS SAS® software (SAS® Institute Inc., 1990a and b). The data base consisted of environmental/sample data, including station sample gear, volume of water filtered, zooplankton biomass estimates, and species identifications and abundance. Two data sets were constructed by LDWF: one for the period of February 1978 to December 1981 called LOOP Plankton Data Base, Card Type 7 (LPDB7) and one for the period of January 1982 to

December 1995 called LOOP Plankton Data Base, Card Type 11 (LPDB11). Due to the problematic nature of the earlier data base, which LDWF had never analyzed, it was necessary as part of Task 2 to incorporate a separate budgetary subcontract to conduct extensive reformatting, recording and in some cases first-time entry of original data directly from raw field and laboratory data sheets, in addition to the extensive QA/QC work traditionally performed on long data sets.

**LOOP plankton data set "LPDB11" (1/82 - 12/95)**

The SAS export file containing LOOP plankton data was obtained through LSU's Computer Services via downloading from the main frame to a PC. The file was then "zipped" up and copied onto diskette. The SAS data sets were imported into a PC environment without complications.

The LPDB11 data set (1/82 - 12/95) used 80-column data formats developed when punch cards were the only means of data entry. This resulted in the construction of one large data set containing both environmental/station data and plankton data. This problem was further complicated by multiple variables used to code special aspects of a sample (i.e., a single sample could have several special codes). Thus, separating the environmental data from the plankton data was a priority during Task 1. Care was taken when dividing the environmental and plankton data sets so that duplicate or redundant observations would not be perpetuated, while not losing valuable information. Some variables were renamed to more descriptive titles. Other variables were combined or completely removed from the data to reduce redundancy or extraneous information. During this process, extreme outliers were checked for validity. The resulting data sets reduced the complexity of the original data, allowing for more efficient tracking of errors.

Much of the first half of the Task 2 time period was devoted to data quality control and management. Volume of water filtered estimates were checked by gear type and by date (since flowmeter design was changed in July 1987). Missing estimates were derived from mean values for a particular gear type/station combination. Biomass estimates, settled

volume and displacement volume, were also carefully scrutinized. Samples where only biomass estimates were made (with no subsequent taxonomic work-up) were added to the data set. A list of 10-digit NODC codes and corresponding scientific names was constructed to merge with the plankton data.

**LOOP plankton data set "LPDB7" (2/78 - 12/81)**

This portion of the LOOP plankton database consisted of data collected at inshore and offshore sampling stations (HS, HL, and OM gear) from the project inception (February 1978) through December 1981 and initially consisted of 15,736 observations, representing 57 stations. This portion of the zooplankton data base was never examined to any great extent by LDWF to determine the validity of certain calculated variables (e.g., plankton tow volume of water filtered and organism densities) or for questionable life history codes, taxonomic codes, or species identifications. Extensive primary QA/QC was performed on this data set to ensure a greater degree of confidence in subsequent analytical results.

One major problem identified by LDWF was missing current numeric taxonomic codes and scientific names for many identified taxa. All observations had the older version of a 1-3 digit LDWF taxonomic code, but many lacked a corresponding 10-digit NODC code (5,043 obs.) and/or scientific name (4,282 obs.). A number of truncated (less than 10 digits) NODC codes in the database had to be corrected. There were 305 identified taxa. Those observations associated with LDWF codes 1-300 were mostly correct. All others (up to 607) had to be extensively checked for accuracy.

Although bongo net sampling was initiated at stations 500, 501, 505, 506, and 507 during September 1981, data collected prior to January 1982 were not entered into the original database by LDWF. The LDWF, however, provided the September to December 1981 bongo data to us in computerized format during Task 2.

As with LPDB11, LPDB7 was divided into two data sets, one containing environmental data and the other plankton data. The LDWF constructed a species list that matched the plankton observations as well as the NODC data. The LDWF also extracted raw data for LPDB7 which allowed us to incorporate missing biomass estimates into the existing database. We entered flowmeter readings to assure volume filtered estimates were complete. LPDB7 was then subjected to the same error checks at LPDB11.

Zooplankton biomass or standing stock estimates (settled and/or displacement volume) are reported in $ml/m^3$, zooplankton densities in $no./m^3$, and ichthyoplankton densities in $no./100m^3$ for individual stations and/or gear by dividing raw measurements or counts or adjusted counts of organisms identified in a (sub) sample by the volume of water filtered. Missing or questionable values for volume of water filtered were replaced by the average volume filtered estimate for that plankton net mesh size at that particular station with tow duration taken into account.

## Analytical Procedures

The LDWF (Ditty et al. 1987; Kasprzak et al. 1994, 1996) have previously described the various cluster analyses and ANOVAs on station surface salinities used to derive the sampling station environmental characterizations and station groupings indicated in Tables 1 and 3.

BACI analyses were performed on the densities ($no./m^3$) of selected organisms and on zooplankton biomass estimates (i.e., settled volume or displacement volume - $ml/m^3$). Densities were log transformed (Ln [(no./volume of water filtered) +1]) before the analyses to attempt to normalize their distribution and the distribution of the model residuals. Statistical diagnostics supported the application of this transformation; however, low occurrences of some species resulted in many zero density values, skewing the distribution to the right. Selection of species for a particular analysis was based on the duration of reliable identifications and on their frequency of occurrence during the time interval of interest. Special consideration was also given to species of commercial or recreational importance.

For a given statistical test on a selected species, all stations (appropriate for the analysis) at which the organism occurred were used in the analysis. The LDWF environmental codes for the remaining no-catch stations were also scrutinized to determine whether or not to include plankton data collected at these stations in the analysis. For example, if a station was assigned an environmental code of "Species not present", that station entered the analysis with a density of zero. Alternatively, a station with an environmental code of "Sample not analyzed" or "Organism removed but not identified" was excluded from the analysis. Similarly, data derived from the biomass estimate method that occurred with the greatest frequency during the time interval of interest were included in the biomass analysis. The relationship between the two biomass estimates was determined for each gear type by linear regression on natural log-transformed values. Missing biomass values were then predicted from the remaining biomass estimate if present.

In general, all BACI or DACI analyses have two main effects: a temporal effect - Before-After (or During-After), which is based upon the dates of the event being studied; and a spatial effect - Control-Impact, which is based upon the proximity to the theorized impacted site(s). Since larval abundances of most estuarine and coastal species are by their very nature seasonal, season was also included as a temporal main effect, along with its various interaction terms with the other two main effects. The resultant model is as follows:

$$\begin{aligned} \text{Ln(Density+1)} = {} & \text{BA} \quad \text{YEAR(BA)} \quad \text{CI} \quad \text{STATION(CI)} \quad \text{BA*CI} \\ & \text{YEAR(BA)*STATION(CI)} \quad \text{SEASON} \quad \text{SEASON*BA} \quad \text{SEASON*CI} \end{aligned}$$

where the interaction terms BA*CI and SEASON*BA*CI test for direct impact. One can simply substitute the During-After (DA) component for the BA in the above model description for the DACI model. Oil spill (Figure 3) and brine discharge data (Figure 4) were also utilized in the appropriate analyses as a covariate with the impacted stations. However, if the covariate effect was not significant, it was removed from the model before interpretation of the results.

The Control-Impact (CI) model is similar to the BACI (or DACI) model except no BA effect is present, as well as any terms containing it. Thus in this model, Year becomes a main effect. Since there is no "impact" term per se, the Oil covariate is used as an indication of impact. A significant Oil term may point towards a negative (or positive) impact on organism density due to the petroleum spill. The resulting model is as follows:

$$\begin{gathered}\text{Ln(Density+1)} = \text{OIL} \quad \text{CI} \quad \text{STATION(CI)} \\ \text{YEAR} \quad \text{SEASON} \quad \text{YEAR*CI} \quad \text{YEAR*STATION(CI)} \\ \text{YEAR*SEASON} \quad \text{SEASON*CI} \quad \text{SEASON*STATION(CI)} \\ \text{YEAR*SEASON*CI}\end{gathered}$$

All BACI, DACI and CI models were tested with the MIXED procedure using restricted maximum likelihood (SAS 1992). For a family of tests, the Bonferroni - corrected alpha is reported to aid in the interpretation of the individual test calculated probabilities. The Bonferroni correction conservatively controls the lower boundary of the family level of significance at 0.05 (Neter et al. 1996).

Failure to detect an interaction in such statistical analyses can result either because the available data do not provide sufficient power to detect the impact, or because there is no discernable impact. A number of factors contribute to the lack of power in a statistical test. In environmental monitoring the reasons for low power are high variability, typical of the experimental material, and small sampling sizes. High variability cannot be controlled by the investigator, but is offset if sample sizes are made large by either intensive sampling or long-term sampling. The lack of a discernable impact can result because there is in fact no impact. However, an actual impact may not be detected if the experimental design is inadequate. Some examples of design inadequacies are poor choices in control stations and failure to sample for seasonal differences.

# RESULTS

## Inshore combined impacts BACI model

To test for Long-term Inshore Combined Impacts associated with LOOP (i.e., construction, related local activities, oil spills, etc.) we conducted a Before-After, Control-Impact (BACI) Mixed Model ANOVA utilizing oil spill data from the Clovelly Salt Dome Storage Facility (station 38, Figure 1) as a covariate. The Before time period was February 1978 to February 1979 and the After time period extended from March 1979 to December 1995. The analysis was run with Season (i.e., Winter = months 1-3, Spring = 4-6, Summer = 7-9, and Fall = 10-12) as a main effect. At these inshore stations, only HL (0.5 m net with 0.0153 - mm mesh) samples were collected. Control and Impact stations were assigned using the most logical station pairings available (Table 3) and modified by the appropriateness or applicability of their respective data time lines (Table 2). Therefore, the Control and Impact stations tested (Table 4) were subsets of those stations potentially available. The small number of taxa tested resulted from the severely limited availability of detailed, consistently-recorded, taxonomic zooplankton and/or ichthyoplankton prior to January 1982.

The predetermined adjusted alpha level using the Bonferroni correction for multiple testing was $P = 0.0167$ for this family of tests (i.e., Mixed Model ANOVA run independently on three taxa). This extended time period (from February 1978 to December 1995) necessitated that we convert zooplankton biomass estimates based upon the settled volume method into zooplankton displacement volume. We fit the following regression model to predict displacement volumes for HL stations: Ln [(displacement vol./vol. of water filtered) + 1] = 0.832 Ln [(settled vol./vol. of water filtered) +1] - 0.438 ($F = 3620.759$; $P \leq 0.0001$; $R^2 = 0.7730$; $N = 1065$). Having done that we noted a marginally significant oil covariate within the BACI Inshore Cumulative Impact Mixed Model ANOVA ($P = 0.0983$, Table 5) which indicated a negative or inverse relationship between oil and zooplankton biomass (Figure 5). No other parameter was significant even when oil was

removed as a covariate within the Mixed Model. No significant oil or main effects were seen in the BACI Inshore Cumulative Impacts Model and no significant main effects were seen when oil was removed from the *Penaeus aztecus* or the Osteichthyes model. However, Osteichthyes displayed a marginally significant Control-Impact interaction ($P = 0.0861$) with Control densities ($27.2/100m^3$) greater than Impact ($14.7/100m^3$).

**Offshore combined impacts BACI model**

We were unable to conduct a similar BACI Combined Impact analysis for Offshore waters because of problems associated with the data time lines (i.e., availability) for the various sampling gears used (i.e., HL, OM, BO, BS, BH, and BHH), the longevity of various stations, a lack of appropriate Control-Impact pairings, and crucial taxonomic identification gaps.

**Inshore construction impacts**

In addition to the Long-term (2/78-12/95) BACI Inshore Combined Impact Mixed Model ANOVA, we also analyzed selected inland pipeline and Clovelly impact and control stations for construction-related impacts only over two shorter time periods: from February 1978 to August 1985 and from February 1978 to March 1983. These two reduced time periods were determined by HL station availability, duration of data time lines, control/impact station pairings, the consistency within the zooplankton taxonomic resolution, and the distributional densities within. Both analyses are equally limited by the lack of larval fish taxonomic resolution during the pre-impact interval (i.e., Class Osteichthyes identification level only). The shorter test interval, however, actually has better zooplankton taxonomic resolution but is occasionally limited by a data gap from August 1982 to March 1983 (e.g., Decapoda, Polychaeta and Gastropoda).

The BACI Inshore Construction Impact model with the longer data set (February 1978 to August 1985) was run on zooplankton biomass, and Osteichthyes and *Penaeus aztecus* densities with season as a main effect for the HL stations only (without oil or brine data

values for Clovelly). The predetermined adjusted alpha level using the Bonferroni correction for multiple testing was P = 0.0167 for this family of tests (i.e., Mixed Model ANOVA run independently on three taxa). No significant Inshore Construction environmental impact results were identified. Of interest, although not significant, was a Control-Impact, seasonal interaction for *Penaeus aztecus* (P = 0.0543; Table 6) where the spring mean density at Impact stations was an order of magnitude greater than the spring Control mean (0.05 postlarvae/$m^3$ vs. 0.005), while Control summer and winter means (0.006 and 0.025) were greater than Impact values (0.004 and 0.002, respectively).

The BACI Inshore Model that utilized the shorter data set (February 1978 to March 1983) was run on *Acartia* spp., Copepoda, Decapoda, Polychaeta, and Gastropoda (without oil or brine data). Our predetermined adjusted alpha level using the Bonferroni correction was P = 0.0100 for this family of tests (i.e., five taxa tested). No significant environmental impact results were identified. *Acartia* spp. displayed a significant seasonal effect (P = 0.0001; Table 7) with winter densities being lower than all other seasons. Also of interest is the Before-After seasonal trend (P = 0.0222) which resulted from Before spring and summer mean densities (3,491 and 1,510/$m^3$) being greater than After (329 and 742/$m^3$, respectively); all other seasonal Before-After groupings were approximately equal. In the Copepoda analysis there was a marginally significant seasonal effect (P = 0.0637) and a significant Before-After seasonal interaction (P = 0.0027) which mostly reflects consistently lower Before densities, especially during fall and winter (Figure 6). The significant Control-Impact seasonal interaction (P = 0.0013), however, reflects an opposing or oscillating trend (e.g., Control > Impact densities during spring and fall, while Impact > Control during summer and winter, Figure 7). The Before-After, Control-Impact seasonal interaction (P = 0.0037) helps explain the inconsistencies in the above analyses and does not reflect a true environmental impact; but rather reflects a much smaller fall mean density for the Before-Impact grouping (Figure 8) and to a lesser extent somewhat lower Before-Control means. The other seasonal means (i.e., After-Control and After-Impact) appeared to be similar. Decapoda had a significant seasonal trend (P = 0.0001) with mean densities lowest during the fall. Additional information is provided by the Before-After seasonal trend (P = 0.0559) which was mostly a reflection of After spring density (8.62/$m^3$) being lower than Before

(20.18). In the Polychaeta analysis, there was a seasonal effect (P = 0.0001) with fall mean densities being the highest (2.51/$m^3$) and winter the lowest (1.50/$m^3$). There was also a Before-After seasonal trend (P = 0.0059) which indicated that After mean densities were consistently higher than Before especially during the fall (Figure 9). The absence of Control-Impact (spatial) interactions makes this appear to be more of an annual trend than an environmental impact. Finally, Gastropoda displayed a highly significant seasonal trend (P = 0.0001) with maximum and minimum mean seasonal densities during summer (4.65/$m^3$) and winter (0.47), respectively.

We also conducted a During- (Construction- 3/79 to 3/81) After, Control-Impact (DACI) Mixed Model ANOVA involving the inland pipeline and Clovelly station data sets extending through August 1985 (without oil or brine data), and excluding the relatively data-poor, pre-impact interval. Here again zooplankton biomass, *Penaeus aztecus* and Osteichthyes were analyzed. We did not run a shorter time span (as we did above) because the previously identified zooplankton data gap (from July 1982 to February 1983) would have adversely affected the shortened, After time period. Our predetermined adjusted alpha level using Bonferroni was P = 0.0167 (i.e., three taxa tested). Within this Inshore Construction DACI model, zooplankton biomass had a significant seasonal interaction (P = 0.0005; Table 8) with highest zooplankton biomass means in winter (2.60) and fall (1.75) compared to spring (1.52) and summer (1.33 ml/$m^3$). Also of interest was the near significant During-After, Control-Impact interaction (P = 0.0428; Figure 10) which showed mean biomass for Impact stations to be greater During (2.17 ml/$m^3$) than After (1.48), while Control means were greater After (1.81) than During (1.70). When Impact station values decrease and Control station values increase in this fashion or even remain the same, it is indicative of possible environmental (construction-related) impact. *Penaeus aztecus* had no significant parameter effects. Osteichthyes had a significant seasonal trend (P = 0.0023) which was mostly a reflection of minimum densities occurring in the fall. The significant During-After seasonal trend (P = 0.0046) revealed higher After mean densities in the spring and winter, while the Before density was higher during the summer (Figure 11). There was also a marginally significant Control-Impact seasonal interaction (P = 0.0962) whereby impact stations had lower mean densities in spring and winter than controls, yet had a higher mean

density during the fall and approximately equal densities in the summer. Therefore, there was no clear environmental impact indicated.

**LOCAP pipeline**

No statistical analysis were conducted on potential environmental impacts associated with the construction or operation of the LOCAP pipeline utilizing the freshwater HS stations (i.e., 24-30, 465, 466, or 483) in the upper reach of the estuary because of their extremely short sampling durations which also did not overlap construction/operation time periods.

**Offshore brine discharge**

We conducted a During-After, Control-Impact (DACI) Offshore Diffuser (i.e., brine disposal site-station 36) Mixed Model ANOVA, using a During time period from May 1980 to November 1983 to encompass the vast majority of continuous brine discharge (Figure 4) and an After time period from December 1983 to December 1995 utilizing the offshore brine disposal data as a covariate and data from the OM stations only. Our predetermined adjusted alpha level using the Bonferroni correction was $P = 0.0036$ (i.e., 14 taxonomic groupings tested). This extended time period (5/80 - 12/95) necessitated that we convert zooplankton settled volumes into zooplankton displacement volumes. We fit the following regression model to predict settled volumes for the OM stations: Ln [(displacement vol./vol. of water filtered) + 1] = 0.665 Ln [(settled vol./vol. of water filtered) + 1] - 0.133 ($F = 3147.357$; $P \leq 0.0001$; $R^2 = 0.8613$; $N = 509$). Having done that, there were no significant brine effects or any significant main effects with or without brine for OM displacement volume (Table 9). However, there was a trend towards After displacement volumes being greater than During (0.36 vs. 0.14 ml/m$^3$; $P = 0.0303$). In fact, no significant brine effects for any of the taxa analyzed under this statistical design were indicated; therefore, we will only discuss the DACI Offshore Diffuser Mixed Model ANOVA results without the incorporation of the brine data set.

Of interest for the *Penaeus aztecus* analysis was a marginally significant seasonal effect (P = 0.0027). Winter *Penaeus aztecus* densities were highest during winter (0.09 postlarvae/$m^3$), and lowest during spring (0.01). *Callinectes sapidus* had a significant seasonal effect (P= 0.0001) with densities highest in summer (0.34 megalopae/$m^3$) and lowest in winter (0.01) and spring (0.09). *Callinectes similis*, *Brevoortia patronus*, Myctophidae, *Sciaenops ocellatus*, Gobiidae, Scombidae, *Peprilus* spp. and Bothidae had no significant main effects. However, *Callinectes similis* had an interesting yet non-significant During-After effect (P = 0.0572) with After densities (0.14 megalopa/$m^3$) being greater than During (0.01); Gobiidae had a slight During-After seasonal trend (P = 0.0333) with spring time After densities (1.4 larvae/100$m^3$) higher than During (0.2) but the situation reversed in the fall (After = 0.2; During = 0.6); and Scombridae had a marginal seasonal trend (P = 0.0194) with densities highest in summer (1.2/100$m^3$) followed by spring (0.7). The DACI Offshore Diffuser analysis for *Anchoa* spp. had a significant seasonal effect (P = 0.0001) with highest densities in summer (97.8 larvae/100$m^3$) and spring (96.3) versus winter (5.3) and fall (1.3) and a somewhat interesting During-After seasonal effect (P = 0.0755) with After summer (120.0 larvae/100$m^3$) and spring (119.3) densities higher than During (summer = 48.4; spring = 43.0) and the remaining seasonal combinations being approximately equal. *Chloroscombrus chrysurus* displayed a significant seasonal trend (P = 0.0001) with highest densities in summer (21.4 larvae/100$m^3$ versus spring and fall = 0.6) with During summer mean density (32.1) being greater than After (17.7 larvae/100$m^3$; During-After seasonal interaction P = 0.0745). *Cynoscion arenarius* also had a marginally significant seasonal trend (P = 0.0071) with mean summer density (14.8) exceeding that for spring (3.1 larvae/100$m^3$). Finally the DACI Offshore Diffuser analysis for Blennidae had a marginal seasonal interaction (P = 0.0117) with spring (5.4) followed by summer densities (2.3 larvae/100$m^3$) being the highest. Also of interest was a During-After effect (P = 0.0713) and During-After seasonal trend (P = 0.0809) where overall After densities were slightly greater than During, especially in spring and summer (Figure 12). The absence of Control-Impact interactions, however, makes this simply a temporal (annual) effect rather than a spatial effect which in combination with a temporal effect would indicate environmental impact.

We conducted another DACI analysis of the Offshore Diffuser (brine disposal) site, using the same During time period (5/80-11/83) and the brine disposal data as a covariate, but using a reduced post-impact period of December 1983 to July 1986, necessitated by trying to utilize the HL station data. There were no detectable brine effects on the HL station zooplankton biomass data, which was the only zooplankton or ichthyoplankton data set that was consistent throughout the time period (i.e., not plagued by the February 1984 through July 1986 organism identification data gap at those stations). The Mixed Model ANOVA was then run without brine. There was a significant seasonal effect (P= 0.0011; Table 10) with spring and summer biomass estimates greater than fall and winter; and a significant During-After seasonal trend (P = 0.0029) with After densities for the winter and spring being greater than Before (Figure 13). Also of interest are the During-After interaction (P= 0.0510) with After biomass estimates greater than During, and the During-After, Control-Impact interaction (P= 0.0566) which had impact stations less than control within the During period and greater than control in the After (Figure 14).

**LOOP marine terminal - April 1990 oil spills**

No oil spill test was conducted on or around the time period of the three LOOP offshore platform spills in April 1990. The HL sampling had been discontinued at stations in the vicinity. The OM sampling in the area was conducted in early April prior to all three April spills. The Bongo net sampling which was conducted between the second and third spill was at control but not impact stations. In addition there was no extended impact or follow-up capability because May 1990 samples were taken but not worked up under the revised ("seven target months") sample processing protocol.

**LOOP marine terminal - long-term oil impacts**

To test for Long-Term, Offshore LOOP Terminal Oil Impacts, we conducted a Control-Impact (CI) Mixed Model ANOVA utilizing oil spill data from the LOOP platform terminal for the period between May 1981 to December 1994. Oil was a covariate and Year and Season were main effects. We used only OM sampling stations, because they had the best

temporal and spacial coverage. We used the previously developed regression for converting OM zooplankton settled volumes to displacement volumes. The reader is cautioned, however, that only zooplankton biomass had data for the complete CI time period. The data sets for the other taxonomic groupings usually ended in 1989 or 1990 and the test time periods were adjusted accordingly. Our predetermined adjusted alpha level using the Bonferroni correction was P = 0.0033 (i.e., 15 taxa tested).

Oil as a covariate was not significant in the zooplankton biomass (displacement volume) analysis, nor were there any significant Control-Impact interactions (Table 11). There were marginally significant or significant seasonal trends with biomass estimates being greatest in spring (0.49 ml/m$^3$) and lowest in summer (0.3 ml/m$^3$) and no clear year (Figure 15) or year-season trends.

For the *Penaeus aztecus* analysis, oil as a covariate was not significant, nor were there any significant Control-Impact interactions. There was a significant seasonal effect (P = 0.0001) and Year-Season interaction (P = 0.0001) and a marginally significant year effect (P = 0.0316). Mean seasonal densities were much higher in winter (0.03 postlarvae/m$^3$; next highest seasonal density occurring in fall = 0.001) which was also reflected in the Year-Season interaction (P = 0.0001) that had an alternating pattern between years with a high density year being followed by a low (Figure 16) especially during the winter and fall seasons.

For the *Callinectes sapidus* analysis, oil as a covariate was not significant. There were, however, significant Control-Impact-Season, Control-Impact-Year, and Control-Impact-Year-Season interactions (P = 0.0001; Table 11) which needed investigation. Those interactions, however, provided no indication of impact as I will explain below. In general spring mean densities (0.28 megalopae/m$^3$) were higher than summer (0.08) and fall (0.05) which were higher than winter (0.008 megalopae/m$^3$; see seasonal effect P = 0.0002). Within the Control-Impact-Season interaction, control mean densities were higher than impact in spring, but impact densities were higher than control in summer. Within the Control-Impact interaction (P = 0.0001) control mean densities were lower than impact in 1981, but

higher in 1982. In general the densities for 1981 and 1982 were much greater than the remaining years (see year effect P = 0.0001; also note no data for 1983). For example the high spring density in 1982 was the dominant source of variation in the Year-Season interaction (P = 0.0001) followed by the high summer and fall densities in 1981. Within the Control-Impact-Year-Season interaction (P = 0.0001), once again 1981 and 1982 provided the dominant source of variation. While both control and impact densities were high in the summer of 1981, impact estimates were much larger than control. However, control densities in the spring of 1982 were much higher than impact, which were also relatively large when compared to other Control-Impact-Year-Season combinations (Figure 17). In other words, there was absolutely no clear trend in any of the above *C. sapidus* data to indicate Offshore LOOP Terminal impact.

For the *C. similis* analysis, oil as a covariate was not significant, nor were there any significant Control-Impact interactions (Table 11). There was a marginally significant seasonal effect (P = 0.0683) with mean densities for winter (0.16 megalopae/$m^3$) and spring (0.14) being higher than summer (0.02) and fall (0.07); and a marginally significant year effect (P = 0.0333) which indicated that 1982 (0.28/$m^3$) and 1989 (0.41/$m^3$) were exceptionally high years (Figure 18). In 1982 spring mean density was the highest, while in 1989 it was the fall and winter (see Year-Season interaction P = 0.0001)

For the *Portunus* spp. analysis, oil as a covariate was not significant, nor were there any significant Control-Impact interactions (Table 11). There was a marginal seasonal effect (P = 0.0066) where highest mean densities were recorded in spring (0.14 megalopae/$m^3$) followed by fall (0.06). There was a significant year effect (P = 0.0018) and Year-Season interaction (P = 0.0007) with highest mean densities seen in 1982 and 1988 (Figure 19) especially during the spring, and a secondary abundance peak in 1985 during the winter.

For the larval fish taxa tested, only *Anchoa* spp. had even a marginally significant oil covariate effect (P = 0.0991; Table 11). The plot of the relationship between *Anchoa* spp. densities and LOOP platform oil spill data, however, is not strong (Figure 20). The inverse or negative relationship is heavily influenced by five observations. In addition, there were

no other impact indications to additionally support the relationship, i.e., no significant Control-Impact interactions. There was a significant seasonal effect (P = 0.0023) with spring mean density (46.86 larvae/100m$^3$) higher than summer (21.3) and winter (1.18; no fall season). Year as a main effect was also significant (P = 0.0006) and revealed an extremely high 1982 density (Figure 21).

For the *Chloroscombrus chrysurus* analysis, oil as a covariate was not significant, but there was a marginally significant Control-Impact-Year-Season interaction (P = 0.0271; Table 11) which warranted further consideration. To help explain this spatial-temporal interaction, we will first discuss its various temporal components. There was a marginally significant year effect (P = 0.0565) which reflected a high annual density for 1982 (18.03 larvae/100m$^3$ and to a much lesser extent for 1985 (5.77; note no 1983 data; Figure 22). The Year-Season interaction was also marginally significant (P = 0.0770; note only analyzed - Spring/Summer and Summer/Fall seasons) which mostly reflected spring/summer densities being higher than summer/fall densities in 1982; whereas the reverse was true in 1985. The Control-Impact-Year-Season interaction was mostly a reflection of control densities during the summer/fall of 1981 (13.97 larvae/100m$^3$) and 1985 (45.27) being an order of magnitude greater than Impact densities (3.84 and 0.81, respectively). Control densities were also an order of magnitude greater in the spring/summer period in 1982 (63.82) than impact (4.24; Figure 23).

The rest of the ichthyoplankton taxa analyses indicated that oil as a covariate was not significant, nor were there any significant Control-Impact interactions. *Cynoscion arenarius, Peprilus* spp., Bothidae and *Symphurus* spp. Had no significant season or year main effects or interactions. Therefore, for the remainder of the Results section, we will just discuss seasonal, yearly or year-season interactions for the remaining taxa tested.

*Brevoortia patronus* had a marginally significant seasonal effect (P = 0.0248; Table 11) with mean winter densities (70.01 larvae/100m$^3$) greater than fall (27.62; no spring and summer seasons). There was also a marginally significant year effect (P = 0.0849) with no

clear annual trend (Figure 24) and a marginally significant Year-Season interaction (P = 0.0656) which indicated that yearly winter densities were greater than fall except in 1986.

Myctophidae had a significant seasonal effect (P = 0.0004) whereby mean winter densities (9.72 larvae/100m$^3$) were an order of magnitude greater than fall (0.96) and spring (0.93; no summer data). There was also a marginally significant year effect (P = 0.0247) which reflected a density maximum in 1988 with a secondary peak in 1985 and 1986. Myctophidae also had a marginally significant Year-Season interaction (P = 0.0962) with no apparent temporal trend, except that the winter season was dominant (Figure 25).

Blennidae had a marginally significant seasonal effect (P = 0.0044) whereby mean densities were highest in spring (7.44 larvae/100m$^3$) and lowest in winter (0.97). The Year-Season interaction was also marginally significant (P = 0.0247) which reflected the general trend of dominant spring densities across years, with the exception of the mean values for the summer of 1982 and the fall of 1986, which were greater than spring mean densities.

Finally, Scombridae had a marginally significant year effect (P = 0.0111; Table 11) which reflected a maximal annual density in 1982 with a secondary peak in 1988 (Figure 26).

## DISCUSSION AND CONCLUSIONS

Only a few statistical analyses had significant or marginally significant Direct LOOP Impact implications (DLI; Table 12), while another test had results which appeared to have Indirect LOOP Impacts (ILI; Table 12). Some test results appear to be related to oil discharge or spills and/or subsequent clean up activities while others to the construction phase. The discussion of marginally significant statistical results ($P \leq 0.1$) is environmentally, ecologically and biologically meaningful, because they clearly suggest that those parameters are sensitive to LOOP - related environmental perturbations.

The zooplankton biomass data set was by far the most complete (longest times series and largest sample size) and had a greater number of significant and/or marginally significant test results. The most interesting test finding resulted from the BACI Long-term, Inshore, Combined Impacts Model (2/78 to 12/95) which had the Clovelly oil spill data as a covariate. Oil as a covariate proved to be marginally significant ($P = 0.0983$) and showed an inverse (negative) relationship with zooplankton biomass (Table 5; Figure 5). Another interesting finding involving zooplankton biomass occurred within the DACI Inshore, Long-term Construction Impacts Model (Table 8) which had a marginally significant ($P = 0.0428$) During-After, Control-Impact interaction whereby mean zooplankton biomass at Impact stations was greater than the Controls (2.17 vs. 1.70 ml/m$^3$) During the construction phase, but was lower than Control estimates (1.40 vs. 1.81 ml/m$^3$) After construction. Perhaps construction disturbances, initially stimulated the standing stock of the zooplankton population which later was depressed by the long-term combination of perturbations. Other times there appeared to be more vague indications of Indirect LOOP impacts, such as the During-After, Control-Impact interaction ($P = 0.0566$; Table 10) seen within the zooplankton biomass data in the DACI Diffuser model run on the HL data set over the May 1980 to July 1986 time period. Mean zooplankton biomass at Impact stations was less than Controls within the During period, but was greater than Controls After (Figure 14).

The Osteichthyes Control-Impact interaction (Control mean densities greater than Impact) within the BACI Inshore Combined Impact Model (P = 0.0861; Table 5) was interesting, but had no additional impact support from the other interactions.

We found no significant impacts associated with brine discharge which appears to be the norm with most such studies in the northcentral Gulf of Mexico. Zooplankton studies conducted in association with the Bryan Mound Strategic Petroleum Reserve (SPR) Project (Park and Minello 1981) reported no significant environmental impacts associated with brine discharge on the inner continental shelf off Texas. However, analysis of zooplankton and ichthyoplankton data collected in association with the West Hackberry SPR Project brine disposal site on the inner shelf off western Louisiana did report significant impacts (Vecchione et al. 1983). Statistical analysis revealed significantly fewer Copepods, fish eggs, larval fish, crab zonae, and *Penaeus* spp. postlarvae at the diffuser site and two of four, near-field impact stations when compared to one of the near-field control stations.

The West Hackberry SPR Project's pre-impact data set consisted of four sampling cruises conducted quarterly (coverage of the four seasons) during 1978-1979 and only two months of sequential sampling in March and April cruise in 1981. The impact time period consisted of 12 monthly sampling trips from May 1981 through April 1982 during brine discharge. The study test results, however, were challenged by outside reviewers. The Department of Energy requested that NOAA's Environmental, Satellite, Data and Information Service (NESDIS) conduct an outside technical review/critique of the findings (Turgeon 1983). That review was critical of the sampling design (inappropriate pre-impact data set - too short and too discontinuous) and of the statistical analysis, and concluded no impacts were detectable. The Vecchione et al. (1983) study also tested for estuarine impacts associated with the water displacement caused by intake for solution mining at the West Hackberry salt dome storage facility. Although they saw a relationship between changes in the community similarity (as measured by the Bray-Curtis Similarity Index) of impact stations and freshwater intake volume, they did not interpret the relationship to be impact related.

As with the oil, brine and construction analyses conducted inshore, the offshore LOOP Terminal Oil Impact analyses, which used the platform oil spill data set as a covariate, produced a number of significant and marginally significant temporal (in this case seasonal and annual) results (Table 11 and 12). However, two (2) test results relate directly to the discussion of LOOP-related environmental impacts. Densities for *Anchoa* spp., a very abundant coastal taxonomic group, displayed a marginally significant (P = 0.0991; Table 11; Figure 20) negative (inverse) relationship with oil spill data as a covariate. This negative relationship was not strong and appeared to be influenced by five large oil spill points. In addition, this negative relationship was not additionally supported by other significant Control-Impact (spatial) interactions, while there were significant temporal relationships found. The second noteworthy impact-related finding occurred with *Chloroscombrus chrysurus*, another very abundant coastal species. *Chloroscombrus chrysurus* displayed a marginally significant Control-Impact-Year Season interaction (P = 0.0271; Table 11; Figure 23). This statistical result was mostly a reflection of the mean density values for the control stations during the summer/fall time period in 1981 and 1985 being an order of magnitude greater than the impact station densities. Control station densities were also an order of magnitude greater than impact during the high abundance peak in the spring/summer period of 1982. Such a statistical finding may be indicative of environmental impact(s) associated with less clearly defined, spatial and temporal events such as relatively small, chronic oil spills.

In any event it is noteworthy that two relatively high abundance taxa showed at least sensitivity to offshore LOOP-related activities. A previous study of ichthyoplankton and offshore oil-related activities had not observed any such indicators. During July and October 1977 and February 1978, an ichthyoplankton study was conducted in and around the Buccaneer Oil Field off Galveston, Texas. No significant differences were seen when comparing oil field to far-field stations. The authors concluded "... that the brine discharge and other possible contaminants from the [oil and gas] platforms did not appear to affect the ichthyoplankton in the oil field." (Finucane et al. 1979; page 2.3.6-ii).

In summary, the negative relationship between the Clovelly oil spill data and zooplankton biomass and the zooplankton biomass During-After, Control-Impact interaction within the DACI Inshore Long-term Construction Model provide the clearest implications for LOOP-related impacts inshore. In the coastal/offshore environment, there were two (2) indicators of potential environmental impact from LOOP-related activities. The Control-Impact, Offshore LOOP Terminal Oil Impact analysis used zooplankton and ichthyoplankton densities, platform oil spill data as a covariate and season and year as main effects. The negative relationship between LOOP offshore terminal oil and *Anchoa* spp. densities and the Control-Impact-Year-Season interaction within the *Chloroscombrus chrysurus* analysis both indicate that these taxa are sensitive to LOOP-related environmental Impact. Clearly when the data sets were large, continuous or involved very abundant taxa, there was the distinct possibility of observing potential environmental impact(s).

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|---|---|---|---|---|---|---|---|---|---|
| 6 | 29°12'37" | 90°06'18" | In channel between Lake Palourde and Bay Macoin, 180 meters W of Bayou Ferblanc | IS<br>LE | 2.7 | 2/78 | 1/82 | M | HL |
| 7<br>(407)<br>(≈462) | 29°15'18" | 90°11'22" | Middle of Lake Jesse, 23 meters E of the ship channel and 600 meters NW of Southwest Louisiana Canal | IS<br>LE | 1.8 | 2/78 | 12/95 | M | HL |
| 8 | 29°15'54" | 90°06'14" | Mouth of Southwest Louisiana Canal, at Bay Lizette | IS<br>LE | 1.8 | 2/78<br>1/95 | 1/82<br>12/95 | M | HL |
| 9 | 29°16'12" | 90°01'56" | Caminada Bay, 27 meters W of Bayou Andre channel light | IS<br>LE | 1.8 | 2/78 | 12/81 | M | HL |
| 10 | 29°14'39" | 90°15'37" | Little Lake, 9 meters W of Marker #1, near entrance of Southwest Louisiana Canal | IS<br>LE | 2.4 | 5/78<br>1/95 | 1/82<br>12/95 | M | HL |
| 11 | 29°20'05" | 90°14'18" | A Texaco canal, midchannel, 180 meters E of intersection with Bayou Lafourche but W of LOOP pipeline | LS<br>IE | 2.4 | 7/78 | 12/81 | M | HL |
| 12<br>(≈40) | 29°24'34" | 90°11'37" | At intersection of a Tennessee Gas Transmission canal and unnamed navigation canal, 1.7 km N of Yankee Canal | LS<br>IE | 1.8 | 7/78<br>12/91 | 3/88<br>5/94 | M | HL |
| 13 | 29°25'24" | 90°09'24" | King's Ridge at old bed of Bayou L'Ours | LS<br>IE | 1.5 | 7/78 | 5/94 | M | HL |
| 14 | 29°31'47" | 90°09'53" | Little Lake, 4 km N of Plum Point, near freshwater injection platform in Exxon/Little Lake Oil and Gas Field | LS<br>UE | 2.1 | 3/78 | 11/95 | M | HL |
| 15<br>(≈464) | 29°30'13" | 90°12'58" | Bay L'Ours at mouth of Superior Canal, near Daymarker #2 | LS<br>UE | 1.8 | 5/78 | 11/95 | M | HL |
| 16 | 29°28'10" | 90°16'53" | Breton Canal, 475 meters W of Bayou Raphael, near pumps on southside of canal at Tidelands Country Club; when canal dammed sta. 39 created in 9/85 | LS<br>UE | 2.4 | 5/78 | 8/85 | M | HL |

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|---|---|---|---|---|---|---|---|---|---|
| 17 | 29°39'57" | 90°09'44" | Bayou Perot, 325 meters E of Delta Farms Oil and Gas Field, 4 km SE of intersection with Intracoastal Waterway | LS<br>UE | 1.5 | 5/78 | 1/82 | M | HL |
| 18 | 29°39'34" | 90°12'52" | Intracoastal Waterway, 2.4 km SW of intersection with Bayou Perot | LS<br>UE | 3.1 | 7/78 | 11/95 | M | HL |
| 19<br>(419) | 29°41'27" | 90°13'15" | Lake Salvador, 3.2 km WNW of intersection of Intracoastal Waterway and Bayou Perot | LS<br>UE | 1.8 | 5/78 | 1/82 | M | HL |
| 20 | 29°41'54" | 90°10'39" | Intracoastal Waterway, 900 meters NE of intersection with Bayou Perot | LS<br>UE | 3.1 | 5/78 | 6/78 | two dates | HL |
| 21 | 29°05'42" | 90°09'39" | Offshore, 45 meters NW of Chevron Platform BM 119 | HS<br>NO | 7.6 | 4/78<br>10/80 | 1/84<br>12/95 | M | HL<br>OM |
| 22<br>(422) | 29°06'16" | 90°06'47" | Offshore, 45 meters NW of Chevron Platform GI 25 14 | HS<br>NO | 11.0 | 4/78<br>11/80 | 1/84<br>12/95 | M | HL<br>OM |
| 23 | 29°09'18" | 90°05'42" | Front Beach, 8 km ENE of mouth of Bay Champagne at Bayou Moreau | IS<br>LE | 3.1 | 6/78 | 6/78 | single date<br>Q | HL |
| 24 | 29°41'32" | 90°28'03" | Company Canal, 750 meters NE of LA. Highway 654 at bend in canal | F | 1.5 | 8/78 | 12/81 | Q | HS |
| 25 | 29°49'48" | 90°37'19" | Bayou Boeuf, 450 meters S of intersection with Grand Bayou | F | 2.4 | 8/78 | 12/81 | Q | HS |
| 26 | 29°49'55" | 90°38'05" | Halpin Canal, 225 meters SW of Bayou Boeuf | F | 1.8 | 8/78 | 12/81 | Q | HS |
| 27 | 29°51'11" | 90°37'51" | Grand Bayou, 250 meters NNW of intersection with Bayou Boeuf | F | 2.1 | 8/78 | 12/81 | Q | HS |
| 28 | 29°55'48" | 90°44'50" | Bayou Chevreuil, at intersection with unnamed canal, 150 meters NW of intersection of Bayou Chevreuil and Dredge Boat Canal | F | 2.4 | 8/78<br>9/79 | 12/81<br>6/81 | Q<br>two dates | HS<br>HL |
| 29 | 29°54'49" | 90°47'54" | Bayou Citamon, near intersection with Grand Bayou | F | 2.4 | 8/78<br>9/79 | 12/81<br>6/81 | Q<br>two dates | HS<br>HL |

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|---|---|---|---|---|---|---|---|---|---|
| 30 | 29°58'16" | 90°52'09" | St. James Canal, at intersection with unnamed canal 320 meters NE of Bayou Traverse | F | 3.1 | 8/78<br>9/79 | 12/81<br>6/81 | Q<br>two dates | HS<br>HL |
| 31 | 29°07'26" | 90°08'20" | Front Beach, near LOOP pipeline crossing, 2.3 km NE of mouth of Bay Champagne | IS<br>LE/TP | 3.1 | 9/78 | 12/81 | M | HL |
| 32 | 29°13'32" | 90°12'08" | A Texaco canal, mid-channel, 2.9 km S of Southwest Louisiana Canal and 1 km E of Bayou Lafourche | IS<br>LE | 2.7 | 3/79 | 12/81 | M | HL |
| 33 | 29°08'53" | 90°12'09" | Flotation canal, 350 meters W of impoundment outfall pipe and 1.9 km ENE of intersection with Bayou Lafourche | IS<br>LE | 3.1 | 3/79 | 12/81 | M | HL |
| 34<br>(434) | 29°07'14" | 90°10'22" | In unnamed canal 290 meters WNW of intersection with Bay Champagne, at Chevron pipeline cross | IS<br>LE/TP | 1.8 | 3/79 | 12/95 | M | HL |
| 35/535<br>(435) | 29°07'22" | 90°05'00" | Offshore, 45 meters W of Hunt Platform GI 24 5;<br>(OM data gap from 12/89-8/94) | HS<br>NO | 10.8 | 9/79<br>9/80<br>4/82<br>1/84 | 1/84<br>12/95<br>12/83<br>12/95 | M | HL<br>OM<br>BS<br>BO |
| 36<br>(≈475) | 29°06'00" | 90°06'54" | Offshore, midpoint of LOOP brine diffuser | HS<br>NO | 11.0 | 2/80<br>8/80 | 1/84<br>12/95 | M | HL<br>OM |
| 37 | 29°08'30" | 90°13'16" | Bayou Lafourche, at flotation canal, 2.8 km N of LOOP small boat harbor | IS<br>LE/TP | 3.1 | 1/80<br>5/86 | 1/84<br>12/95 | M | HL<br>OM |
| 38<br>(≈463) | 29°28'28" | 90°15'18" | Clovelly, at freshwater intake | LS<br>UE | 2.0 | 2/80 | 12/95 | M | HL |
| 39 | 29°28'23" | 90°16'11" | Breton Canal, 30 meters E of Hurricane Protection levee; station created when canal dammed between sta.'s 16 and 38; (data gap from 9/88 to 2/89) | LS<br>UE | 2.0 | 9/85 | 11/95 | M | HL |

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|---|---|---|---|---|---|---|---|---|---|
| 40<br>(≈12) | 29°24'26" | 90°11'11" | 800 meters E of intersection of Tennessee Gas Transmission canal and unnamed navigational canal, 1.7km N of Yankee Canal | LS<br>IE | 1.8 | 4/88 | 11/91 | M | HL |
| 41 | 29°20'08" | 90°30'00" | Middle of Lake Tambour | IS<br>LE | 1.8 | 3/78 | 2/84 | M | HL |
| 42 | 29°08'40" | 90°30'30" | Terrebonne Bay, 1000 meters W of Terrebone Island | IS<br>LE/TP | 2.1 | 2/78 | 2/84 | M | HL |
| 43 | 29°04'12" | 90°31'30" | Off front beach, 1100 meters SW of western tip of Timbalier Island | IS<br>LE/TP | 2.4 | 2/78 | 2/84 | M | HL |
| 44 | 28°55'54" | 90°31'30" | Offshore, 13.4 km S of Timbalier Island | HS<br>NO | 9.2 | 2/78 | 2/84 | M | HL |
| 50 | 28°48'32" | 90°04'35" | Offshore, 700 meters SE of Continental Oil Platform CAGC GI 63 A | HS<br>FO | 37.0 | 9/79<br>6/79 | 9/79<br>12/79 | single date<br>Q<br>two dates | HL<br>OM |
| 51 | 28°56'42" | 90°01'51" | Offshore, 900 meters SE of Continental Oil Platform CAGC GI 47 A AQ | HS<br>FO | 28.0 | 9/79<br>6/79 | 9/79<br>12/79 | single date<br>Q<br>two dates | HL<br>OM |
| 52<br>(482) | 28°54'48" | 89°59'05" | Offshore, 4.8 km NE of LOOP pumping platform | HS<br>FO | 34.0 | 6/80<br>1/82<br>6/80 | 12/81<br>2/84<br>12/95 | Q<br>M<br>M | HL<br>HL<br>OM |
| 53<br>(481) | 28°53'06" | 90°01'30" | Offshore, 90 meters NW of LOOP pumping platform | HS<br>FO | 34.0 | 6/80<br>1/82<br>6/80 | 12/81<br>2/84<br>10/86 | Q<br>M<br>M | HL<br>HL<br>OM |
| 54<br>(479) | 28°56'12" | 90°04'07" | Offshore, 300 meters W of Continental Platform CAGC GI 48 K | HS<br>FO | 27.0 | 6/80<br>1/82<br>6/80 | 12/81<br>2/84<br>10/86 | Q<br>M<br>M | HL<br>HL<br>OM |
| 55 | 28°51'48" | 90°01'31" | Offshore, 400 meters S of LOOP platform | HS<br>FO | 34.5 | 2/82<br>2/82 | 2/84<br>12/95 | M | HL<br>OM |

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|---|---|---|---|---|---|---|---|---|---|
| 407 (7) (≈462) | 29°15'18" | 90°11'22" | Middle of Lake Jesse, 23 meters E of the ship channel and 600 meters NW of Southwest Louisiana Canal | IS LE | 1.8 | 5/80 | 8/80 | two dates Q | HL |
| 419 (19) | 29°41'27" | 90°13'15" | Lake Salvador, 3.2 km WNW of intersection of Intracoastal Waterway and Bayou Perot | LS UE | 1.8 | 8/79 | 8/79 | single date Q | HL |
| 422 (22) | 29°06'16" | 90°06'47" | Offshore, 50 meters W of Chevron Platform GI 25 14 | HS NO | 11.0 | 8/79 | 4/80 | two dates Q | HL |
| 434 (34) | 29°07'14" | 90°10'22" | In unnamed canal, 290 meters WNW of intersection with Bay Champagne, at Chevron pipeline crossing | LS UE | 1.8 | 8/79 | 8/80 | three dates Q | HL |
| 435 (35/535) | 29°07'22" | 90°05'00" | Offshore, 45 meters W of Hunt Platform GI 24 5 | HS NO | 10.8 | 8/79 | 9/80 | four dates Q | HL |
| 460 | 29°07'47" | 90°08'45" | Bayou Moreau, 6 meters W of LOOP pipeline | IS LE/TP | 2.4 | 5/80 | 8/80 | two dates Q | HL |
| 461 | 29°28'41" | 90°15'53" | At intersection of unnamed canals, 500 meters W of LOCAP pipeline | LS UE | 1.0 | 2/80 | 8/80 | two dates Q | HL |
| 462 (≈7) (≈407) | 29°15'17" | 90°11'46" | Lake Jesse near LOOP pipeline, 90 meters from W bank | IS LE | 0.9 | 5/80 | 8/80 | two dates Q | HL |
| 463 (≈38) | 29°28'32" | 90°15'19" | Clovelly, 50 meters N of freshwater intake, at canal entrance | LS UE | 1.7 | 2/80 | 8/80 | two dates Q | HL |
| 464 (≈15) | 29°30'07" | 90°13'03" | Mouth of Superior Canal at Bay L'Ours | LS UE | 2.7 | 8/80 | 8/80 | single date Q | HL |
| 465 | 29°46'42" | 90°37'42" | Theriot Canal, 640 meters N of Monterey Oil Co. gas pipeline and 90 meters S of mouth at Lake Boeuf | F | 1.1 | 1/80 | 1/80 | single date Q | HS |
| 466 | 29°46'26" | 90°37'46" | Theriot Canal, 90 meters S of Monterey Oil Co. gas pipeline and 1.6 km N of intersection with Halpin Canal | F | 1.4 | 1/80 | 8/80 | three dates Q | HS |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 467 | 29°06'17" | 90°07'45" | Offshore, 50 meters W of Chevron Platform BMI 54 | HS NO | 8.8 | 3/81 | 11/81 | two dates * Q | OM |
| 468 | 29°05'59" | 90°07'18" | Offshore, 50 meters W of Chevron Platform GI 25 16 | HS NO | 9.8 | 3/81 | 11/81 | two dates * Q | OM |
| 469 | 29°05'47" | 90°07'36" | Offshore, 50 meters W of Chevron Platform GI 25 19 | HS NO | 9.5 | 3/81 | 11/81 | two dates * Q | OM |
| 470 | 29°05'26" | 90°07'23" | Offshore, 50 meters W of Chevron Platform GI 25 SE | HS NO | 10.4 | 3/81 | 11/81 | two dates * Q | OM |
| 471 | 29°05'14" | 90°06'58" | Offshore, 50 meters W of Chevron Platform GI 26 P | HS NO | 12.2 | 3/81 | 11/81 | two dates * Q | OM |
| 472 (≈502) | 29°05'48" | 90°06'39" | Offshore, 50 meters W of Chevron Platform GI 25 13 | HS NO | 11.0 | 3/81 | 11/81 | two dates * Q | OM |
| 473 | 29°06'01" | 90°06'48" | Offshore, 150 meters E of diffuser | HS NO | 8.8 | 3/81 | 11/81 | two dates * Q | OM |
| 474 | 29°05'52" | 90°06'53" | Offshore, 150 meters S of diffuser | HS NO | 8.8 | 3/81 | 11/81 | two dates * Q | OM |
| 475 (≈36) | 29°06'01" | 90°07'00" | Offshore, 150 meters W of diffuser | HS NO | 9.5 | 3/81 | 11/81 | Q | OM |
| 476 | 29°06'11" | 90°06'55" | Offshore, 150 meters N of diffuser | HS NO | 8.5 | 3/81 | 11/81 | two dates * Q | HL |
| 477 | 29°02'09" | 90°05'48" | Offshore, 30 meters W of LOOP pipeline at 15 meter depth contour | HS FO | 15.2 | 4/80 | 11/81 | Q | OM |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 478 | 29°02'09" | 90°05'12" | Offshore, 800 meters E of station 477 | HS<br>FO | 15.2 | 4/80 | 11/81 | Q | OM |
| 479<br>(54) | 28°56'12" | 90°04'07" | Offshore, 300 meters W of Continental platform CAGC GI 48K | HS<br>FO | 27.0 | 4/80 | 11/81 | Q | OM |
| 480 | 28°56'10" | 90°03'35" | Offshore, 320 meters E of Continental platform CAGC GI 48K | HS<br>FO | 27.0 | 4/80 | 11/81 | Q | OM |
| 481<br>(53) | 28°53'06" | 90°01'30" | Offshore, 90 meters NW of LOOP pumping platform | HS<br>FO | 34.0 | 4/80 | 11/81 | Q | OM |
| 482<br>(52) | 28°54'48" | 89°59'05" | Offshore, 4.8 km NE of LOOP pumping platform | HS<br>FO | 34.0 | 4/80 | 11/81 | Q | OM |
| 483 | 29°45'57" | 90°38'02" | Theriot Canal, 650 meters N of intersection with Halpin Canal | F | 1.1 | 5/80 | 8/80 | two dates<br>Q | HS |
| 484 | 28°51'04" | 90°04'18" | Offshore, 4.8 km SW of LOOP pumping platform | HS<br>FO | 34.0 | 8/80 | 11/81 | four dates<br>Q | OM |
| 485 | 28°51'58" | 90°00'55" | Offshore, midway between SPM 104 and SPM 103 | HS<br>FO | 37.0 | 8/80 | 11/81 | four dates<br>Q | OM |
| 486 | 28°52'45" | 90°00'09" | Offshore, midway between SPM 103 and SPM 102 | HS<br>FO | 34.0 | 8/80 | 11/81 | four dates<br>Q | OM |
| 500 | 29°06'14" | 90°07'06" | Offshore, 500 meters N of LOOP diffuser | HS<br>NO | 9.0 | 9/81 | 12/83 | M | BS |
| 501 | 29°05'47" | 90°07'06" | Offshore, 500 meters W of LOOP diffuser | HS<br>NO | 9.0 | 9/81 | 12/83 | M | BS |
| 502<br>(≈472) | 29°05'50" | 90°06'41" | Offshore, 500 meters S of LOOP diffuser | HS<br>NO | 10.0 | 9/81<br>1/84<br>8/86 | 12/83<br>12/95<br>6/90 | M | BS<br>BO<br>OM |
| 505 | 29°05'44" | 90°05'10" | Offshore, 2.9 km SE of LOOP diffuser | HS<br>NO | 11.0 | 9/81 | 12/83 | M | BS |
| 506 | 29°05'14" | 90°07'04" | Offshore, 1.4 km SW of LOOP diffuser | HS<br>NO | 10.0 | 9/81 | 12/83 | M | BS |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 507 | 29°05'22" | 90°06'08" | Offshore, 1.8 km S of LOOP diffuser | HS<br>NO | 11.0 | 9/81<br>1/84 | 12/83<br>7/86 | M | BS<br>BO |
| 535/35<br>(435) | 29°07'22" | 90°05'00" | Offshore, 45 meters W of Hunt Platform GI 24 5;<br>(OM data gap from 12/89-8/94) | HS<br>NO | 10.8 | 9/79<br>9/80<br>4/82<br>1/84 | 1/84<br>12/95<br>12/83<br>12/95 | M | HL<br>OM<br>BS<br>BO |
| 701 | 29°05'48" | 90°06'42" | Offshore, 300 meters SSE of LOOP diffuser | HS<br>NO | 9.7 | 8/83 | 8/83 | single date | BO |
| 704 | 28°59'46" | 90°04'59" | Offshore, 11.9 km SSE of LOOP diffuser<br>(BH data gap between 8/86-8/87) | HS<br>FO | 19.4 | 1/84<br>8/87 | 12/95<br>4/90 | M | BH<br>OM |
| 706 | 28°56'30" | 90°04'10" | Offshore, 7.6 km NNW of LOOP platform | HS<br>FO | 26.1 | 8/83<br>1/84<br>8/86 | 8/83<br>12/95<br>4/90 | single date<br>M | BHH<br>BH<br>OM |
| 708 | 28°53'03" | 90°01'30" | Offshore at LOOP platform | HS<br>FO | 33.0 | 8/83<br>1/84<br>8/86 | 8/83<br>12/95<br>2/90 | single date<br>M | BHH<br>BH<br>OM |
| 711 | 28°47'05" | 90°08'46" | Offshore, 16.3 km SW of LOOP platform | HS<br>FO | 33.5 | 8/86<br>8/86 | 7/87<br>7/87 | M | BH<br>OM |
| 713 | 28°50'57" | 90°09'54" | Offshore, 14.3 km WSW of LOOP platform | HS<br>FO | 27.4 | 8/86<br>8/86 | 7/87<br>7/87 | M | BH<br>OM |
| 719 | 29°02'34" | 90°13'07" | Offshore, 4.3 km SSE of Belle Pass | HS<br>NO | 9.1 | 8/86<br>8/86 | 7/87<br>7/87 | M | BH<br>OM |
| 788<br>(708N) | 28°53'41" | 90°01'42" | Offshore, 1 km NNW of LOOP platform | HS<br>FO | 32.6 | 8/83<br>8/83 | 8/83<br>8/83 | single date | BH<br>OM |
| 798<br>(708S) | 28°52'32" | 90°01'11" | Offshore, 1 km SSE of LOOP platform | HS<br>FO | 34.4 | 8/83<br>8/83 | 8/83<br>8/83 | single date | BH<br>OM |

1 Sea state, % cloud cover, air and water temperature, salinity, secchi extinction depth, and wind speed and direction measured at all zooplankton/ichthyoplankton stations.

2 Modified after Louisiana Department of Wildlife and Fisheries' environmental characterization codes: F = Fresh (<1 ppt); LS = Low Salinity (1-11 ppt); Intermediate Salinity (14-24 ppt); HS = High Salinity (≥ 24 ppt); UE = Upper Estuary; IE = Intermediate Estuary; LE = Lower Estuary; TP = Tidal Pass; NO = Near Offshore; and FO = Far Offshore.

3 M = monthly Q = quarterly.

* Due to proximity of these stations, only one plankton tow was taken at station 475 to cover all nearby stations (i.e., 467, 468, 469, 470, 471, 472, 473, 474 & 476) from 10/79 to 11/81.

HS = Half meter ring net, 0.080 mm net (Small) mesh, surface tow at approx. 1 m/s (2 knots) for 1 minute at upper estuarine freshwater stations

HL = Half meter ring net, 0.153 mm net (Large) mesh, surface tow at approx. 1 m/s for 1 minute at Upper Estuarine, Lower Estuarine, Near-offshore, and Far-offshore stations.

OM = One Meter ring net, 0.363 mm net mesh, surface tow at approx. 1 m/s for 3-5 minutes at one estuarine station (37) and at Near-offshore, Far-offshore and selected bongo stations 500, 501, 502, 505, 506, 507, 535, 701, 704, 706, 708, 711, 713, 719, 788, and 798.

BS = Bongo Stratified (corresponds to LDWF code TMB-BONG-H) = Bongo nets, 60cm, opening and closing (Tareq and Co., Inc., Miami, FL - BNF-1 paired net frame), 0.363 mm net mesh, towed simultaneously at surface, mid- and near-bottom depths, at approx. 1 m/s for 3-5 minutes, at selected offshore stations.

BH = Bongo Half oblique (LDWF code TB-BONG-OBL) = Bongo nets, 60cm, opening and closing (Tareq - BNF-1), 0.363 mm net mesh, simultaneous, stepped-oblique, half-water column tows (i.e., near-bottom to mid-depth and mid-depth to surface), tow speed approx. 1 m/s at selected offshore stations.

BHH = Bongo Half Horizontal (LDWF code TB-BONG-H) Bongo nets, 60cm, opening and closing (Tareq - BNF-1), 0.363 mm net mesh simultaneously towed at 1 m/s horizontally at top and bottom of water column for 3-5 minutes at selected offshore stations.

BO = Bongo Oblique (LDWF code BONG-OBL) = Bongo nets, 60cm, 0.363 mm net mesh towed at 1 m/s in a stepped oblique fashion throughout the whole water column at selected offshore stations.

Table 2. Time lines (i.e., start and finish dates) for study time periods and major events and for zooplankton and ichthyoplankton data by station and sampling gear. Note, however, that occasional small gaps within the actual zooplankton/ichthyoplankton data sets for station time lines are not indicated. For example during December 1987, no faunal identifications were made at stations numbered ≤ 39 for gear codes HL and OM (see Table 1 for gear code definitions). Also, only those stations which had greater than three sampling dates are indicated; therefore, stations 20, 23, 50, 51, 407, 419, 422, 434, 460-466, 483, 701, 788, 798, and 28 HL, 29 HL, and 30 HL are not included. Letters within parentheses are gear codes; stations without gear codes are HL stations. For a given station a date within a bracket represents a start or finish date that differs slightly from the station group's time line. Years with solid black circles (●), which continue after the X's and the station's faunal identification end date, indicate time periods when only zooplankton settled or displacement volumes may have been recorded. See additional comments on Table 1. Asterisks on construction ending date indicates that there is a range in completion dates for the various environments from June 1980, when all inshore LOOP pipeline backfilling completed, to November 1980 when the 48" MOL (oil carrying) line to shore was completed, to March 1981, when all pipelines were completed except for fittings.

| TIME PERIOD/EVENT | 1978 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRE-IMPACT | 2/78<br>P | P<br>2/79 | | | | | | | | | | | | | | | | |
| CONSTRUCTION | | 3/79<br>C | C | C*<br>3/81 | | | | | | | | | | | | | | |
| BRINE DISPOSAL (vast majority) | | | 5/80<br>B | B | B | B<br>11/83 | | | | | | | | | | | | |
| STATIONS | | | | | | | | | | | | | | | | | | |
| 5, 7, 14 [3/78-11/95] | 2/78<br>X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 1, 2, 3, 4 [-6/85]<br>(data gap from 9/83 to 1/84) | 2/78<br>X | X | X | X | X | X<br>8/83 | 2/84<br>X | X<br>11/85 | | | | | | | | | | |
| 41 [3/78-], 42, 43, 44 | 2/78<br>X | X | X | X | X | X | X<br>2/84 | | | | | | | | | | | |
| 6, 8, 9 [-12/81]<br>(8 restart 1995) | 2/78<br>X | X | X | X | X<br>1/82 | | | | | | | | | | | | | X |
| 21 (HL), 22 (HL) | 4/78<br>X | X | X | X | X | X | X<br>1/84 | ● | ●<br>7/86 | | | | | | | | | |
| 15 | 5/78<br>X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X<br>11/95 |
| 16 | 5/78<br>X | X | X | X | X | X | X | X<br>8/85 | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10, 17, 19<br>(10 restart 1995) | 5/78<br>X | X | X | X | X<br>1/82 | | | | | | | | | | | | | X |
| 18 | 7/78<br>X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X<br>11/95 |
| 12 (+40), 13 | 7/78<br>X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X<br>5/94 | |
| 11 [7/78-], 31 [9/78-] and (quarterly HS sta.'s 24, 25, 26, 27, 28, 29, 30) | 8/78<br>X | X | X | X<br>12/81 | | | | | | | | | | | | | | |
| 34 | | 3/79<br>X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 32, 33 | | 3/79<br>X | X | X<br>12/81 | | | | | | | | | | | | | | |
| 435 | | 8/79<br>X | X<br>9/80 | | | | | | | | | | | | | | | |
| 35/535 (HL) | | 9/79<br>X | X | X | X | X | X<br>1/84 | • | •<br>7/86 | | | | | | | | | |
| 502 (OM) | | 10/7<br>9<br>X | X | X<br>11/81 | | | | | 8/86<br>X | X | X | X | X<br>6/90 | • | • | • | • | • |
| 38 | | | 2/80<br>X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 36 (HL), 37 (HL) | | | 2/80<br>X | X | X | X | X<br>1/84 | • | •<br>7/86<br>36 | • | • | • | • | • | • | • | • | •<br>37 |
| 477, 478, 479, 480, 481, 482, 484 [8/80-] (All OM) | | | 4/80<br>X | X<br>11/81 | | | | | | | | | | | | | | |
| 52 (OM) | | | 6/80<br>X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 53 (OM), 54 (OM) | | | 6/80<br>X | X | X | X | X | X | X<br>10/86 | | | | | | | | | |
| 52, 53, 54 (All HL) | | | 6/80<br>X | X | X | X | X<br>2/84 | • | •<br>8/86 | | | | | | | | | |
| 36 (OM), 35/535 (OM) [9/80-] (Sta. 35/535 data gap from 12/89-8/94) | | | 8/80<br>X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 484, 485, 486 (All OM) | | | 8/80<br>X | X<br>11/81 | | | | | | | | | | | | | | |
| 21 (OM), 22 (OM) [11/80-] | | | 10/80<br>X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 475 (≈ 467 to 474 and 476) (All OM) | | | | 3/81<br>X<br>11/81 | | | | | | | | | | | | | | |
| 500, 501, 502, 505, 506, 507 (All BS) | | | | 9/81<br>X | X | X<br>12/83 | | | | | | | | | | | | |
| 55 (OM) | | | | | 2/82<br>X | X | X | X | X | X | X | X | X | X | X | X | X | X |
| 55 (HL) | | | | | 2/82<br>X | X | X<br>2/84 | • | •<br>8/86 | | | | | | | | | |
| 35 (BS), 535 (BS) | | | | | 4/82<br>X | X<br>12/83 | | | | | | | | | | | | |
| 35/535 (BO), 502 (BO), 704 (BH-gap between 8/86 and 8/87), 706 (BH), 708 (BH) | | | | | | | 1/84<br>X | X | X | X | X | X | X | X | X | X | X | X |
| 507 (BO) | | | | | | | 1/84<br>X | X | X<br>7/86 | | | | | | | | | |
| 39 (data gap from 9/88 to 2/89) | | | | | | | | 9/85<br>X | X | X | X | X | X | X | X | X | X | X<br>11/95 |
| 37 (OM) | | | | | | | | | 5/86<br>X | X | X | X | X | X | X | X | X | X |
| 502 [-6/90], 704 [8/87-], 706, 708 [-2/90] (All BH and OM) | | | | | | | | | 8/86<br>X | X | X | X | X<br>4/90 | • | • | • | • | • |
| 711, 713, 719 (All BH & OM) | | | | | | | | | 8/86<br>X | X<br>7/87 | | | | | | | | |

Table 3. List of impact and control test stations and the source of their potential perturbation(s) used in statistical analyses of environmental impact. Station numbers within parentheses are either at the same or equivalent (≈) locations.

| IMPACT TEST STATIONS | POTENTIAL PERTURBATION | CONTROL TEST STATIONS |
|---|---|---|
| 7 (407) (≈462) | P | 1, 6, 8, 9, 10, 12 (40), 13, 32, 33, 37, 41 |
| 11 | P | 1, 12 (40), 13, 14, 18, 41 |
| 31, 460† | P | 2, 3, 4, 5, 6, 33, 34 (434), 37, 42, 43 |
| 466, 483† | P | 25, 26, 27, 30 |
| 24, 28, 29 | P-FF | 17, 19, 25, 26, 27, 30 |
| 15 (≈464), 16 | C-FF | 1, 12 (40), 13, 14, 18 |
| 38 (≈463), 39 | C, P | 1, 12 (40), 13, 14, 18 |
| 36, 475* | D | 21, 22 (422), 35/535 (435), 44, 500, 501, 502, 505, 506, 507, 719 |
| 53 (481), 55, 485, 486, 708 | LT | 52 (482), 54 (479), 477, 478, 480, 484, 704, 706, 711, 713 |

C = Clovelly Salt Dome Storage Facility construction, operational and/or brine/oil discharge impacts.
D = Diffuser construction and/or brine discharge impacts.
FF = Far-Field.
LT = LOOP Terminal construction, operational and/or oil discharge impacts.
P = Pipeline construction and/or operational impacts.

Note: Stations 20, 23, 50, 51, 419, 460, 461, 465, 466, 483, 701, 788, and 798 have been dropped from these analyses due to negligible sample sizes (represented by only 1-3 collections).

*Note: Due to their proximity, only one (1), one-meter, surface plankton tow was taken at station 475 from 10/79-11/81 to represent the stations 467, 468, 469, 470, 471, 472, 473, 474, and 476.

† Note: These two pipeline test groupings were not specifically analyzed because the impact station sampling durations either were too short or did not overlap sufficiently with sampling intervals for control stations to allow "before and after" or "during and after" statistical analyses.

Table 4. Summary of statistical analyses used to investigate potential environmental impacts resulting from LOOP related activities. Listed are the type of statistical model used, type of impact tested for, the time period defined within each test, the LDWF zooplankton/ichthyoplankton stations used and divided into impact and controls, and the taxonomic groupings used. BACI = Before-After, Control-Impact statistical design. DACI = During-After, Control-Impact statistical design. See Table 1 for definitions of HL, BO, BH, BS, and BHH station gears. N = Total number of stations available for analysis; + sign indicates a positive station (i.e., a station at which that organism was collected).

| | | Time Period | | | Stations Used | | |
|---|---|---|---|---|---|---|---|
| Statistical Model | Type of Impacts | Before | During | After | Control | Impact | Taxonomic Groupings |
| BACI, ANOVA Mixed Model | Inshore, Long-term Combined Impacts - with oil data with season (main effect); HL stations only; See Table 5 for statistical results. | 2/78-2/79 | | 3/79-12/95 | 7<br>(407)<br>(≈462)<br>11<br>15<br>(≈464)<br>16<br>38<br>(≈463)<br>39 | 1 13<br>6 14<br>8 18<br>9 32<br>10 33<br>12 37<br>(40) 41 | Zooplankton biomass (displacement vol.); N = 2070<br>*Penaeus aztecus*; N = 1835 with 106 + sta.'s; excluded 2/78<br>c. Osteichthyes; N = 1727 with 766 + sta.'s; starts 3/78 and no data from 2-4/82 |
| BACI, ANOVA Mixed Model | Inshore, Long-term Construction Impacts - without oil or brine data with season (main effect) for pipeline & Clovelly; maximizing longevity of stations while minimizing variability of extraneous transient stations; HL stations only; See Table 6. | 2/78-2/79 | | 3/79-8/85 | 7<br>(407)<br>(≈462)<br>15<br>(≈464)<br>16 | 1<br>12<br>13<br>14<br>18 | Zooplankton biomass (settled vol.); N = 613<br>*Penaeus aztecus*; No fall (only 1 + sta.) and excluded sta. 16 (no catch); N = 412 with 24 + sta.'s<br>c. Osteichthyes; N = 581 with 301 + sta.'s |
| BACI, ANOVA Mixed Model | Inshore Construction Impacts Reduced Time Interval - without oil or brine data with season (main effect) for pipeline & Clovelly; maximizing more detailed zooplankton data set early in study; HL stations only; See Table 7. | 2/78-2/79 | | 3/79-3/83 | 7<br>(407)<br>(≈462)<br>15<br>(≈464)<br>16 | 1 13<br>6 14<br>8 18<br>9 41<br>10<br>12 | *Acartia* spp.; excluded stations where no copepods were identified; excluded nauplii; N = 550 with 489 + sta.'s<br>Copepoda; minus *Acartia* spp.; N = 550 with 513 + sta.'s<br>Decapoda; includes *Penaeus aztecus*; N = 423 with 264 + sta.'s<br>Polychaeta; N = 543 with 200 + sta.'s<br>Gastropoda; N = 543 with 184 + sta.'s |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| DACI, ANOVA Mixed Model | Inshore, Long-term Construction Impacts -no pre-impact data; without oil or brine data with season (main effect) for pipeline & Clovelly; maximizing longevity of stations especially those which started later while minimizing variability of extraneous stations; HL stations only; See Table 8. | | 3/79-3/81 | 4/81-8/85 | 7<br>15<br>16<br>38<br>(≈463) | 1 18<br>12 37<br>13 41<br>14 | Zooplankton biomass (settled vol.); N = 674<br>*Penaeus aztecus*; no fall (only 2 + sta.'s); N = 640 with 41 + sta.'s<br>c. Osteichthys; data gap 2/80-4/80; N = 642 with 355 + sta.'s |
| DACI, ANOVA Mixed Model | Long-term Offshore Brine Disposal - Diffuser - with and without brine data with season (main effect); contains gap in detailed zooplankton data (2/84-7/86); maximizes longevity of appropriate stations; OM stations only; See Table 9. | | 5/80-11/83 | 12/83-12/95 | 36<br>(475) | 21<br>22<br>(422)<br>35/535 | Zooplankton biomass (displacement vol.); N = 666<br>*Penaeus aztecus*; N = 470 with 194 + sta.'s<br>*Callinectes sapidus* (megalopa); N = 462 with 253 + sta.'s; During starts 1/81 with first occurrence<br>*C. similis* (megalopa); N = 460 with 253 + sta.'s; During starts 1/81 with first occurrence<br>*Brevoortia patronus* (includes all *Brevoortia* spp. larvae; N = 308 with 209 + sta.'s; just two seasons putting Apr. into Winter and Sept. into Fall; During starts 12/80<br>*Anchoa* spp. (includes Engraulidae, *A. hepsetus* and *A. mitchilli*); N = 441 with 275 + sta.'s; During starts 2/81<br>Myctophidae (includes *Diaphus* spp., *Lampanyctus* spp. and *Hygophum* spp.) N = 238 with 82 + sta.'s but low abundance; only Winter (months 11, 12 + 1) and Spring (months 2, 3 + 4); During starts 1/81 with first occurrence<br>*Chloroscombrus chrysurus*; N = 322 with 123 + sta.'s; excludes Winter; During starts 5/81 with first occurrence<br>*Cynoscion arenarius*; N = 208 with 102 + sta.'s; excluded Winter - 10 observations and Fall - 9 observations; During starts 4/82 with first occurrence<br>*Sciaenops ocellatus*; N = 92 with 71 + sta.'s; instead of by Season model run on Month = 8, 9 and 10; During starts 8/81; due to small sample sizes model is weak<br>Blennidae (includes *Hypsobennius hentzi*, *Ophioblennius* spp., and *Scartella cristata*); N = 437 with 194 + sta.'s; During starts 3/81 with first occurrence<br>Gobiidae (includes *Gobionellus hastatus* now renamed *G. oceanicus*); N = 444 with 84 + sta.'s but low abundances; During starts 1/81 with first occurrence<br>Scombridae; N = 420 with 43 + sta.'s but low abundances; During starts 7/81 with first occurrence<br>*Peprilus* spp. [includes *P. alepidotus* (≈*P. paru*), *P. burti*, and Stomateidae]; N = 429 with 52 + sta.'s but low abundances; During starts 4/81 with first occurrence<br>Bothidae; N = 442 with 72 + sta.'s but low abundances; during starts 1/81 with first occurrence |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| DACI,<br>ANOVA<br>Mixed<br>Model | Reduced Long-term Offshore Brine Disposal - Diffuser - with and without brine data with season (main effect); insufficient detailed zooplankton data due to data gap (2/84-7/86); maximizing longevity of stations while minimizing variability of extraneous transient stations and of a long After time period; HL stations only; See Table 10. | | 5/80-11/83 | 12/83-7/86 | 36<br>(475) | 21<br>22<br>(422)<br>35/535 | Zooplankton biomass (settled vol.); N = 263 |
| CI<br>ANOVA<br>Mixed<br>Model | Long-term Offshore LOOP Terminal Oil Impact-with LOOP offshore terminal oil data (which ends 12/94) as a covariate and year and season as main effects; no pre-impact and no after impact; maximizing longevity of stations while minimizing variability of extraneous transient stations; OM stations only;<br>** data start and end dates used within the indiv. taxonomic analyses varies - see Taxonomic Groupings column; see Table 11. | | 5/81*-<br>12/94*<br>(see Type of Impact column notes) | | 53<br>(481)<br>55<br>486<br>708 | 52<br>(482)<br>54<br>(479)<br>704<br>706 | Zooplankton biomass (displacement vol.); N = 642<br>*Penaeus aztecus* (postlarvae); data outside of 8/82 to 2/90 time period too sparse to analyze; N = 322 with 95 + sta.'s<br>*Callinectes sapidus* (megalopa); no 1983 data; data analyzed from 5/81 to 12/89; N = 302 with 113 + sta.'s<br>*C. similis* (megalopa); data analyzed from 5/81 to 2/90; N = 344 with 168 + sta.'s<br>*Portunus* spp. (megalopa); data analyzed from 4/82 to 12/89; N = 318 with 149 + sta.'s<br>*Brevoortia patronus* (includes *B. gunteri*); no Spring and Summer seasons; data analyzed from 10/82 to 2/90; N = 158 with 134 + sta.'s<br>*Anchoa* spp. (includes Engralidae, *A. hepsetus* and *A. mitchilli*); data analyzed from 6/81 to 9/89; no Fall; N = 247 with 154 + sta.'s<br>Myctophidae (includes *Centrobranchus nigrocellatus, Diagenichthys altanticus, Notoscopelus resplendens, Diaphus* spp., *Gonichthys* spp., *Hygophum* spp., *Lampanyctus* spp., and *Myctophum* spp.); data analyzed from 5/82 to 2/90; no Summer; N = 244 with 109 + sta.'s<br>*Chloroscombrus chrysurus*; no 1983 data; just two seasons - Spr./Sum. = months 5, 6 and 7 and Sum./Fall = months 8, 9 and 10; N = 145 with 71 + sta.'s<br>*Cynoscion arenarius*; no Fall data; data analyzed from 4/82 to 9/89; N = 239 with 64 + sta.'s; low abundance<br>Blennidae (includes *Hypoblennius* spp. and *Ophioblennius* spp.); data analyzed from 8/81 to 6/89; N = 310 with 179 + sta.'s<br>Scombridae; no Winter; just two seasons - Spr./Sum = months 4, 5 and 6 and Sum./Fall = months 7, 8, 9 and 10; N = 190 with 74 + sta.'s<br>*Peprilus* spp. [includes *P. alepidotus* (≈ *P. paru*), *P. burti* and Stomateidae]; no Summer; data analyzed from 11/81 to 3/88; N = 194 with 71 + sta.'s<br>Bothidae; data analyzed from 5/81 to 6/89; N = 315 with 70 + sta.'s; low abundance<br>*Symphurus* spp. (includes *S. plagiusa* and Cynoglossidae); no Winter; data analyzed from 5/81 to 9/89; N = 248 with 76 + sta.'s; low abundance |

Table 5. Before-After, Control-Impact (BACI) inshore LOOP combined impacts mixed model ANOVA with a seasonal (Winter = months 1-3, Spring = 4-6, Summer = 7-9, and Fall = 10-12) main effect (HL gear) for the 2/78 - 12/95 time period. Clovelly oil was entered as a covariate in the displacement volume model. See Table 4 for details.

Displacement Volume with oil covariate

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| OIL | 1 | 1745 | 2.74 | 0.0983 |
| BA | 1 | 16 | 1.49 | 0.2394 |
| CTRLIMPC | 1 | 17 | 1.59 | 0.2243 |
| BA*CTRLIMPC | 1 | 175 | 0.15 | 0.6977 |
| SEASON | 3 | 1745 | 1.95 | 0.1192 |
| BA*SEASON | 3 | 1745 | 2.25 | 0.0811 |
| CTRLIMPC*SEASON | 3 | 1745 | 0.73 | 0.5363 |
| BA*CTRLIMPC*SEASON | 3 | 1745 | 0.74 | 0.5292 |

Penaeus aztecus

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| BA | 1 | 17 | 0.29 | 0.5970 |
| CTRLIMPC | 1 | 17 | 0.63 | 0.4370 |
| BA*CTRLIMPC | 1 | 183 | 0.01 | 0.9398 |
| SEASON | 3 | 1602 | 1.30 | 0.2713 |
| BA*SEASON | 3 | 1602 | 1.08 | 0.3563 |
| CTRLIMPC*SEASON | 3 | 1602 | 0.19 | 0.9061 |
| BA*CTRLIMPC*SEASON | 3 | 1602 | 0.36 | 0.7799 |

Osteichthyes

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| BA | 1 | 17 | 0.02 | 0.8803 |
| CTRLIMPC | 1 | 17 | 3.32 | 0.0861 |
| BA*CTRLIMPC | 1 | 183 | 0.29 | 0.5937 |
| SEASON | 3 | 1494 | 1.49 | 0.2143 |
| BA*SEASON | 3 | 1494 | 0.33 | 0.8030 |
| CTRLIMPC*SEASON | 3 | 1494 | 0.38 | 0.7651 |
| BA*CTRLIMPC*SEASON | 3 | 1494 | 0.45 | 0.7153 |

Table 6. BACI inshore LOOP construction impacts mixed model ANOVA with a seasonal main effect (HL gear) for the LOOP pipeline and the Clovelly Salt Dome Storage Facility for the 2/78 - 8/85 time period. See Table 4 for details.

*Penaeus aztecus*

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| BA | 1 | 7 | 0.01 | 0.9416 |
| CTRLIMPC | 1 | 5 | 1.05 | 0.3527 |
| BA*CTRLIMPC | 1 | 47 | 1.22 | 0.2750 |
| SEASON | 2 | 341 | 1.68 | 0.1878 |
| BA*SEASON | 2 | 341 | 0.54 | 0.5859 |
| CTRLIMPC*SEASON | 2 | 341 | 2.94 | 0.0543 |
| BA*CTRLIMPC*SEASON | 2 | 341 | 0.42 | 0.6597 |

Osteichthyes

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| BA | 1 | 6 | 0.13 | 0.7260 |
| CTRLIMPC | 1 | 6 | 0.23 | 0.6489 |
| BA*CTRLIMPC | 1 | 54 | 0.22 | 0.6404 |
| SEASON | 3 | 499 | 1.54 | 0.2026 |
| BA*SEASON | 3 | 499 | 0.55 | 0.6476 |
| CTRLIMPC*SEASON | 3 | 499 | 0.38 | 0.7697 |
| BA*CTRLIMPC*SEASON | 3 | 499 | 0.86 | 0.4627 |

Settled Volume

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| BA | 1 | 7 | 0.47 | 0.5132 |
| CTRLIMPC | 1 | 6 | 0.02 | 0.8853 |
| BA*CTRLIMPC | 1 | 55 | 0.18 | 0.6729 |
| SEASON | 3 | 529 | 1.98 | 0.1164 |
| BA*SEASON | 3 | 529 | 0.83 | 0.4768 |
| CTRLIMPC*SEASON | 3 | 529 | 0.33 | 0.8033 |
| BA*CTRLIMPC*SEASON | 3 | 529 | 0.42 | 0.7379 |

Table 7. BACI inshore LOOP construction impacts mixed model ANOVA with a seasonal main effect (HL gear) for the LOOP pipeline and the Clovelly Salt Dome Storage Facility for a reduced time period (2/78 - 3/83). See Table 4 for details.

*Acartia* spp.

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| BA | 1 | 5 | 0.00 | 0.9560 |
| CTRLIMPC | 1 | 11 | 0.21 | 0.6561 |
| BA*CTRLIMPC | 1 | 65 | 0.05 | 0.8228 |
| SEASON | 3 | 453 | 14.49 | 0.0001 |
| BA*SEASON | 3 | 453 | 3.23 | 0.0222 |
| CTRLIMPC*SEASON | 3 | 453 | 1.99 | 0.1140 |
| BA*CTRLIMPC*SEASON | 3 | 453 | 0.94 | 0.4194 |

Copepoda

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| BA | 1 | 5 | 0.98 | 0.3683 |
| CTRLIMPC | 1 | 11 | 0.23 | 0.6421 |
| BA*CTRLIMPC | 1 | 65 | 2.80 | 0.0991 |
| SEASON | 3 | 453 | 2.44 | 0.0637 |
| BA*SEASON | 3 | 453 | 4.79 | 0.0027 |
| CTRLIMPC*SEASON | 3 | 453 | 5.30 | 0.0013 |
| BA*CTRLIMPC*SEASON | 3 | 453 | 4.56 | 0.0037 |

Decapoda

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| BA | 1 | 3 | 0.99 | 0.3936 |
| CTRLIMPC | 1 | 11 | 0.05 | 0.8246 |
| BA*CTRLIMPC | 1 | 43 | 2.30 | 0.1366 |
| SEASON | 2 | 354 | 40.96 | 0.0001 |
| BA*SEASON | 2 | 354 | 2.91 | 0.0559 |
| CTRLIMPC*SEASON | 2 | 354 | 0.21 | 0.8076 |
| BA*CTRLIMPC*SEASON | 2 | 354 | 1.56 | 0.2114 |

Polychaeta

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| BA | 1 | 3 | 0.99 | 0.3936 |
| CTRLIMPC | 1 | 11 | 0.05 | 0.8246 |
| BA*CTRLIMPC | 1 | 43 | 2.30 | 0.1366 |
| SEASON | 2 | 354 | 40.96 | 0.0001 |
| BA*SEASON | 2 | 354 | 2.91 | 0.0559 |
| CTRLIMPC*SEASON | 2 | 354 | 0.21 | 0.8076 |
| BA*CTRLIMPC*SEASON | 2 | 354 | 1.56 | 0.2114 |

Gastropoda

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| BA | 1 | 4 | 0.46 | 0.5351 |
| CTRLIMPC | 1 | 11 | 0.06 | 0.8132 |
| BA*CTRLIMPC | 1 | 58 | 2.15 | 0.1478 |
| SEASON | 3 | 454 | 10.73 | 0.0001 |
| BA*SEASON | 3 | 454 | 1.78 | 0.1492 |
| CTRLIMPC*SEASON | 3 | 454 | 0.59 | 0.6191 |
| BA*CTRLIMPC*SEASON | 3 | 454 | 1.21 | 0.3050 |

Table 8. During-After, Control-Impact (DACI) inshore LOOP construction impacts mixed model ANOVA with a seasonal main effect (HL gear) for the LOOP pipeline and the Clovelly Salt Dome Storage Facility for the 3/79 - 8/85 time period. See Table 4 for details.

Settled Volume

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 6 | 0.07 | 0.7973 |
| CTRLIMPC | 1 | 8 | 0.00 | 0.9967 |
| DA*CTRLIMPC | 1 | 60 | 4.28 | 0.0428 |
| SEASON | 3 | 584 | 5.97 | 0.0005 |
| DA*SEASON | 3 | 584 | 0.96 | 0.4098 |
| CTRLIMPC*SEASON | 3 | 584 | 1.28 | 0.2806 |
| DA*CTRLIMPC*SEASON | 3 | 584 | 0.46 | 0.7093 |

*Penaeus aztecus*

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 6 | 1.89 | 0.2183 |
| CTRLIMPC | 1 | 8 | 0.34 | 0.5733 |
| DA*CTRLIMPC | 1 | 60 | 2.20 | 0.1428 |
| SEASON | 3 | 580 | 0.96 | 0.4125 |
| DA*SEASON | 3 | 580 | 1.10 | 0.3485 |
| CTRLIMPC*SEASON | 3 | 580 | 0.61 | 0.6088 |
| DA*CTRLIMPC*SEASON | 3 | 580 | 0.79 | 0.4986 |

Osteichthyes

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 6 | 0.12 | 0.7372 |
| CTRLIMPC | 1 | 8 | 0.14 | 0.7174 |
| DA*CTRLIMPC | 1 | 60 | 2.46 | 0.1219 |
| SEASON | 3 | 552 | 4.90 | 0.0023 |
| DA*SEASON | 3 | 552 | 4.39 | 0.0046 |
| CTRLIMPC*SEASON | 3 | 552 | 2.12 | 0.0962 |
| DA*CTRLIMPC*SEASON | 3 | 552 | 0.38 | 0.7652 |

Table 9. DACI offshore brine disposal (Diffuser) impacts mixed model ANOVA with a seasonal main effect (OM gear) at the offshore diffuser for the 5/80 - 12/95 time period.

Displacement Volume

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 15 | 5.72 | 0.0303 |
| CTRLIMPC | 1 | 2 | 0.00 | 0.9718 |
| DA*CTRLIMPC | 1 | 47 | 0.09 | 0.7637 |
| SEASON | 3 | 586 | 0.87 | 0.4552 |
| DA*SEASON | 3 | 586 | 2.03 | 0.1086 |
| CTRLIMPC*SEASON | 3 | 586 | 0.36 | 0.7815 |
| DA*CTRLIMPC*SEASON | 3 | 586 | 0.56 | 0.6419 |

*Penaeus aztecus*

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 15 | 1.78 | 0.2016 |
| CTRLIMPC | 1 | 2 | 0.33 | 0.6261 |
| DA*CTRLIMPC | 1 | 44 | 0.06 | 0.8027 |
| SEASON | 3 | 393 | 4.79 | 0.0027 |
| DA*SEASON | 3 | 393 | 0.76 | 0.5151 |
| CTRLIMPC*SEASON | 3 | 393 | 0.74 | 0.5279 |
| DA*CTRLIMPC*SEASON | 3 | 393 | 0.03 | 0.9929 |

*Callinectes sapidus* (megalopa)

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 14 | 0.13 | 0.7284 |
| CTRLIMPC | 1 | 2 | 0.16 | 0.7301 |
| DA*CTRLIMPC | 1 | 41 | 0.07 | 0.7860 |
| SEASON | 3 | 389 | 7.85 | 0.0001 |
| DA*SEASON | 3 | 389 | 0.50 | 0.6794 |
| CTRLIMPC*SEASON | 3 | 389 | 0.65 | 0.5839 |
| DA*CTRLIMPC*SEASON | 3 | 389 | 0.19 | 0.9054 |

*Callinectes similis* (megalopa)

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 14 | 4.29 | 0.0572 |
| CTRLIMPC | 1 | 2 | 0.00 | 0.9926 |
| DA*CTRLIMPC | 1 | 41 | 0.03 | 0.8546 |
| SEASON | 3 | 387 | 0.62 | 0.6051 |
| DA*SEASON | 3 | 387 | 0.73 | 0.5353 |
| CTRLIMPC*SEASON | 3 | 387 | 0.86 | 0.4623 |
| DA*CTRLIMPC*SEASON | 3 | 387 | 0.83 | 0.4756 |

*Brevoortia patronus*

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 15 | 1.11 | 0.3097 |
| CTRLIMPC | 1 | 2 | 0.00 | 0.9596 |
| DA*CTRLIMPC | 1 | 39 | 0.67 | 0.4188 |
| SEASON | 1 | 244 | 0.48 | 0.4913 |
| DA*SEASON | 1 | 244 | 1.03 | 0.3105 |
| CTRLIMPC*SEASON | 1 | 244 | 1.32 | 0.2517 |
| DA*CTRLIMPC*SEASON | 1 | 244 | 1.88 | 0.1713 |

*Anchoa* spp.

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 14 | 3.08 | 0.1010 |
| CTRLIMPC | 1 | 2 | 0.00 | 0.9684 |
| DA*CTRLIMPC | 1 | 38 | 0.17 | 0.6835 |
| SEASON | 3 | 371 | 18.45 | 0.0001 |
| DA*SEASON | 3 | 371 | 2.32 | 0.0755 |
| CTRLIMPC*SEASON | 3 | 371 | 0.03 | 0.9936 |
| DA*CTRLIMPC*SEASON | 3 | 371 | 0.07 | 0.9769 |

Myctophidae

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 14 | 2.72 | 0.1211 |
| CTRLIMPC | 1 | 2 | 0.00 | 0.9826 |
| DA*CTRLIMPC | 1 | 38 | 0.00 | 0.9771 |
| SEASON | 1 | 176 | 0.30 | 0.5841 |
| DA*SEASON | 1 | 176 | 1.24 | 0.2660 |
| CTRLIMPC*SEASON | 1 | 176 | 0.01 | 0.9388 |
| DA*CTRLIMPC*SEASON | 1 | 176 | 0.07 | 0.7908 |

*Chloroscombrus chrysurus*

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 14 | 1.20 | 0.2926 |
| CTRLIMPC | 1 | 2 | 0.57 | 0.5291 |
| DA*CTRLIMPC | 1 | 38 | 0.66 | 0.4201 |
| SEASON | 2 | 256 | 25.28 | 0.0001 |
| DA*SEASON | 2 | 256 | 2.62 | 0.0745 |
| CTRLIMPC*SEASON | 2 | 256 | 0.47 | 0.6226 |
| DA*CTRLIMPC*SEASON | 2 | 256 | 0.41 | 0.6647 |

*Cynoscion arenarius*

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 12 | 0.06 | 0.8182 |
| CTRLIMPC | 1 | 2 | 0.92 | 0.4382 |
| DA*CTRLIMPC | 1 | 32 | 0.73 | 0.3978 |
| SEASON | 1 | 154 | 7.45 | 0.0071 |
| DA*SEASON | 1 | 154 | 1.71 | 0.1929 |
| CTRLIMPC*SEASON | 1 | 154 | 1.20 | 0.2758 |
| DA*CTRLIMPC*SEASON | 1 | 154 | 1.05 | 0.3062 |

*Sciaenops ocellatus*

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 13 | 2.48 | 0.1396 |
| CTRLIMPC | 1 | 2 | 0.00 | 0.9709 |
| DA*CTRLIMPC | 1 | 34 | 0.02 | 0.8900 |
| MONTH | 2 | 31 | 0.79 | 0.4642 |
| DA*MONTH | 2 | 31 | 1.61 | 0.2164 |
| CTRLIMPC*MONTH | 2 | 31 | 1.09 | 0.3473 |
| DA*CTRLIMPC*MONTH | 2 | 31 | 0.78 | 0.4672 |

Blennidae

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 14 | 3.81 | 0.0713 |
| CTRLIMPC | 1 | 2 | 0.52 | 0.5453 |
| DA*CTRLIMPC | 1 | 38 | 0.77 | 0.3859 |
| SEASON | 3 | 367 | 3.72 | 0.0117 |
| DA*SEASON | 3 | 367 | 2.26 | 0.0809 |
| CTRLIMPC*SEASON | 3 | 367 | 0.46 | 0.7088 |
| DA*CTRLIMPC*SEASON | 3 | 367 | 0.57 | 0.6331 |

Gobiidae

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 14 | 0.89 | 0.3603 |
| CTRLIMPC | 1 | 2 | 0.20 | 0.6960 |
| DA*CTRLIMPC | 1 | 38 | 0.01 | 0.9175 |
| SEASON | 3 | 374 | 1.73 | 0.1612 |
| DA*SEASON | 3 | 374 | 2.93 | 0.0333 |
| CTRLIMPC*SEASON | 3 | 374 | 0.28 | 0.8381 |
| DA*CTRLIMPC*SEASON | 3 | 374 | 0.26 | 0.8516 |

Scombridae

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 14 | 0.00 | 0.9955 |
| CTRLIMPC | 1 | 2 | 0.20 | 0.7013 |
| DA*CTRLIMPC | 1 | 38 | 0.16 | 0.6872 |
| SEASON | 3 | 350 | 3.35 | 0.0194 |
| DA*SEASON | 3 | 350 | 0.23 | 0.8769 |
| CTRLIMPC*SEASON | 3 | 350 | 0.47 | 0.7068 |
| DA*CTRLIMPC*SEASON | 3 | 350 | 0.16 | 0.9206 |

*Peprilus* spp.

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 14 | 0.71 | 0.4150 |
| CTRLIMPC | 1 | 2 | 0.32 | 0.6292 |
| DA*CTRLIMPC | 1 | 38 | 0.81 | 0.3736 |
| SEASON | 3 | 359 | 0.22 | 0.8815 |
| DA*SEASON | 3 | 359 | 1.07 | 0.3624 |
| CTRLIMPC*SEASON | 3 | 359 | 0.20 | 0.8991 |
| DA*CTRLIMPC*SEASON | 3 | 359 | 0.09 | 0.9657 |

Bothidae

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| DA | 1 | 14 | 2.78 | 0.1176 |
| CTRLIMPC | 1 | 2 | 1.95 | 0.2970 |
| DA*CTRLIMPC | 1 | 38 | 1.56 | 0.2194 |
| SEASON | 3 | 372 | 0.73 | 0.5340 |
| DA*SEASON | 3 | 372 | 0.67 | 0.5716 |
| CTRLIMPC*SEASON | 3 | 372 | 0.98 | 0.4026 |
| DA*CTRLIMPC*SEASON | 3 | 372 | 1.21 | 0.3069 |

*Symphurus* spp.

| Source | NDF | DDF | Type III F | Pr > F |
|---|---|---|---|---|
| OIL | 1 | 163 | 0.00 | 0.9511 |
| CTRLIMPC | 1 | 5 | 1.19 | 0.3250 |
| SEASON | 2 | 10 | 0.44 | 0.6531 |
| CTRLIMPC*SEASON | 2 | 10 | 0.31 | 0.7399 |
| YEAR | 8 | 17 | 1.77 | 0.1530 |
| CTRLIMPC*YEAR | 8 | 17 | 0.69 | 0.6933 |
| YEAR*SEASON | 15 | 163 | 0.88 | 0.5900 |
| CTRLIMPC*YEAR*SEASON | 15 | 163 | 0.29 | 0.9954 |

Table 12. Summary of parameters tested and their specific environmental impact test results which are given within the parentheses as actual P values for main effects, covariates or interactions versus the Bonferroni adjusted alpha values for that family of multiple tests. Also provided are test interpretation codes: Significant (S), Marginally Significant (MS), and Non-Significant (NS) with a probable explanation of significant observed differences, i.e., Direct Loop Impact (DLI), Indirect LOOP Impact (ILI), or Non-LOOP Impact (NLI). Also presented is a probable explanation of why marginally significant or non-significant responses were found, i.e., Parameter Insensitive to LOOP operations (PI), Parameter Sensitive But Variability too high to detect significant differences with the sampling design used (PSBV), or Parameter Sensitive to LOOP operations, but LOOP operations Not Implicated (PSNI). The reader is referred to Appendix Tables A-2 to A-7 for a listing of all biological parameters used (zooplankton and ichthyoplankton monthly mean densities across all years with number of positive sampling stations and standard deviations needed to calculate 95% confidence limits and/or coefficients of variation). See Tables 5-11 for test results.

| Parameter Tested | Specific Test Results | Sig. Code | Prob. Explanation for Sig. or Marginal Sig. | Prob. Reason for Marginal Sig. or Non-Sig. |
|---|---|---|---|---|
| Zooplankton biomass estimate (settled +/or displacement vol. - ml/m$^3$) | BACI Inshore Combined Impact on pipeline and Clovelly with oil as a covariate (2/78-12/95) (P = 0.0983 vs. 0.0167) | MS | DLI | PSBV |
| | BACI Inshore Construction (2/78 - 8/85) | NS | | PSBV |
| | DACI Inshore Construction (3/79 - 8/85) | | | |
| | • Seasonal effect ( P = 0.0005 vs. 0.0167) | S | NLI | |
| | • During-After, Control-Impact interaction (P = 0.0428 vs. 0.0100) | MS | DLI | PSBV |
| | DACI Offshore Diffuser with brine as a covariate OM data only (5/80 - 12/95) | NS | | PSBV |
| | • Model rerun with no brine data - During-After interaction (P = 0.0303 vs. 0.0036) | MS | NLI | PSBV |
| | DACI Offshore Diffuser with brine as covariate HL data only (5/80 - 7/86) | NS | | PSBV |
| | • No brine data - Seasonal effect (P = 0.0001) | S | NLI | |
| | • No brine data - During-After effect (P = 0.0510) | MS | NLI | PSBV |
| | • No brine data - During-After Seasonal interaction (P = 0.0029) | S | NLI | |
| | • No brine data - During-After, Control-Impact interaction (P = 0.0566) | MS | ILI | PSBV |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (5/81 - 12/94) | NS | | PSBV |
| | • Seasonal effect (P = 0.0162 vs. 0.0033) | MS | NLI | PSNI |
| | • Year effect (P = 0.0078 vs. 0.0033) | MS | NLI | PSNI |
| | • Year - Season interaction (P = 0.0003 vs. 0.0033) | S | NLI | |
| *Penaeus aztecus* | BACI Inshore Combined Impact with oil as a covariate (2/78-12/95) | NS | | PSBV |
| | BACI Inshore Construction (2/78 - 8/85) | NS | | PSBV |
| | • Control-Impact Seasonal interaction (P = 0.0543 vs. 0.0167) | MS | NLI | PSBV |
| | DACI Inshore Construction (3/79 - 8/85) | NS | | PSBV |
| | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PSBV |
| | • No brine data - Seasonal effect (P = 0.0027 vs. 0.0036) | MS | NLI | PSNI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (6/82 - 2/90) | NS | | PSBV |
| | • Season effect (P = 0.0001 vs 0.0033) | S | NLI | |
| | • Year effect ( P = 0.0316 vs 0.0033) | MS | NLI | PSNI |
| | • Year Season interaction (P = 0.0001 vs 0.0033) | S | NLI | |

| Parameter Tested | Specific Test Results | Sig. Code | Prob. Explanation for Sig. or Marginal Sig. | Prob. Reason for Marginal Sig. or Non-Sig. |
|---|---|---|---|---|
| *Callinectes sapidus* | BACI Inshore Combined Impact with oil as a covariate (2/78-12/95) | NS | | PSBV |
| | • No brine data - Seasonal effect (P = 0.0001 vs. 0.0036) | S | NLI | |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (5/81 to 12/89 but no 1983 data) | NS | | PSBV |
| | • Seasonal effect (P = 0.0002 vs. 0.0033) | S | NLI | |
| | • Control-Impact Seasonal interaction (P = 0.0005 vs. 0.0033) | S | NLI | |
| | • Year effect (P = 0.0001 vs. 0.0003) | S | NLI | |
| | • Control-Impact Yearly interaction (P = 0.0001 vs. 0.0033) | S | NLI | |
| | • Year Season interaction (P = 0.0001 vs. 0.0033) | S | NLI | |
| | • Control-Impact, Year Season interaction (P = 0.0001 vs. 0.0033) | S | NLI | |
| *C. similis* | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PSBV |
| | • No brine data - During-After effect (P = 0.0572 vs. 0.0036) | MS | NLI | PSBV |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (5/81 to 2/90) | NS | | PSBV |
| | • Seasonal effect (P = 0.0683 vs. 0.0033) | MS | NLI | PSNI |
| | • Year effect (P = 0.0333 vs. 0.0033) | MS | NLI | PSNI |
| | • Year Season interaction (P = 0.0001 vs. 0.0033) | S | NLI | |
| *Acartia* spp. | BACI Inshore Construction Impact (2/78 - 3/83) | NS | | PSBV |
| | • Seasonal effect ( P = 0.0001 vs. 0.0100) | S | NLI | |
| | • Before-After Seasonal interaction (P= = 0.0222 vs. 0.0100) | MS | NLI | PSNI |
| Copepoda | BACI Inshore Construction Impact (2/78 - 3/83) | NS | | PSBV |
| | • Seasonal effect (P = 0.0637 vs. 0.0100) | MS | NLI | PSBV |
| | • Before-After Seasonal interaction (P = 0.0027 vs. 0.0100) | S | NLI | |
| | • Control-Impact Seasonal interaction (P = 0.0013 vs. 0.0100) | S | NLI | |
| | • Before-After, Control-Impact Seasonal interaction (P = 0.0037 vs. 0.0100) | MS | NLI | PSNI |
| Decapoda | BACI Inshore Construction Impact (2/78 - 3/83) | NS | | PSBV |
| | • Seasonal effect (P = 0.0001 vs. 0.0100) | S | NLI | |
| | • Before-After Seasonal interaction (P = 0.0559 vs. 0.0100) | MS | NLI | PSNI |
| Polychaeta | BACI Inshore Construction Impact (2/78 - 3/83) | NS | | PSBV |
| | • Seasonal effect (P = 0.0001 vs. 0.0100) | S | NLI | PSBV |
| | • Before-After Seasonal interaction (P = 0.0059 vs. 0.0100) | MS | NLI | PSBV |
| Gastropoda | BACI Inshore Construction Impact (2/78 - 3/83) | NS | | PSBV |
| | • Seasonal effect (P = 0.0001 vs. 0.0100) | S | NLI | |

| Parameter Tested | Specific Test Results | Sig. Code | Prob. Explanation for Sig. or Marginal Sig. | Prob. Reason for Marginal Sig. or Non-Sig. |
|---|---|---|---|---|
| c. Osteichthyes | BACI Inshore Combined Impact with oil as covariate (2/78-12/95) | NS | | PSBV |
| | • No oil data - Control-Impact interaction (P = 0.0861 vs. 0.0167) | MS | DLI | PSBV |
| | BACI Inshore Construction Impact (2/78 - 8/85) | NS | | PSBV |
| | DACI Inshore Construction (3/79 - 8/85) | | | |
| | • Seasonal effect (P = 0.0033 vs. 0.0100) | S | NLI | |
| | • During-After Seasonal interaction (P = 0.0046 vs. 0.0100) | S | NLI | |
| | • Control-Impact Seasonal interaction (P = 0.0962 vs. 0.0100) | MS | NLI | PSBV |
| *Brevoortia patronus* | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PSBV |
| | • No brine data | NS | | PSBV |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (10/82 to 2/90) | NS | | PSBV |
| | • Seasonal effect (P = 0.0248 vs. 0.0033) | MS | NLI | PSBV |
| | • Year effect (P = 0.0849 vs. 0.0033) | MS | NLI | PSBV |
| | • Year Season interaction (P = 0.0656 vs. 0.0033) | MS | NLI | PSBV |
| *Anchoa* spp. | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PSBV |
| | • No brine data - Seasonal effect (P = 0.0001 vs. 0.0036) | S | NLI | |
| | • No brine data - During-After Seasonal interaction (P = 0.0755 vs. 0.0036) | MS | NLI | PSBV |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (6/81 to 9/89) (P = 0.0991 vs. 0.0033) | MS | DLI | PSBV |
| | • Seasonal effect (P = 0.0023 vs. 0.0033) | S | NLI | |
| | • Year effect (P = 0.0023 vs. 0.0033) | S | NLI | |
| Myctophidae | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data | NS | | PI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (5/82 - 2/90) | NS | | PSBV |
| | • Seasonal effect (P = 0.0004 vs. 0.0033) | S | NLI | |
| | • Year effect (P = 0.0247 vs. 0.0033) | MS | NLI | PSBV |
| | • Year Season interaction (P = 0.0962 vs. 0.0033) | MS | NLI | PSBV |
| *Sciaenops ocellatus* | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data | NS | | PI |
| *Chloroscombrus chrysurus* | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PSBV |
| | • No brine data - Seasonal effect (P = 0.0001 vs. 0.0036) | S | NLI | |
| | • No brine data - During-After Seasonal interaction (P = 0.0745 vs. 0.0036) | MS | NLI | PSNI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (8/81 to 9/89 but no 1983 data) | NS | | PSBV |
| | • Year effect (P = 0.0565 vs. 0.0033) | MS | NLI | PSBV |
| | • Year Season interaction (P = 0.0770 vs. 0.0033) | MS | NLI | PSBV |
| | • Control-Impact, Year Season interaction (P = 0.0271 vs. 0.0033) | MS | DLI | PSBV |
| *Cynoscion arenarius* | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PSBV |
| | • No brine data - Seasonal effect (P = 0.0071 vs. 0.0036) | MS | NLI | PSNI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (4/82 to 9/89) | NS | | PSBV |

| Parameter Tested | Specific Test Results | Sig. Code | Prob. Explanation for Sig. or Marginal Sig. | Prob. Reason for Marginal Sig. or Non-Sig. |
|---|---|---|---|---|
| Blennidae | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data - Seasonal effect (P = 0.0117 vs. 0.0036) | MS | NLI | PI |
| | • No brine data - During-After effect (P = 0.0713 vs. 0.0036) | MS | NLI | PSBV |
| | • No brine data - During-After Seasonal interaction (P = 0.0809 vs. 0.0036) | MS | NLI | PSBV |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (8/81 to 6/89) | NS | | PSBV |
| | • Seasonal effect (P = 0.0044 vs. 0.0033) | MS | NLI | PSBV |
| | • Year Season interaction (P = 0.0247 vs. 0.0033) | MS | NLI | PSBV |
| Gobiidae | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data - During-After Seasonal interaction (P = 0.0333 vs. 0.0036) | MS | NLI | PI |
| Scombridae | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data - Seasonal effect (P = 0.0194 vs. 0.0036) | MS | NLI | PI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (8/81 to 9/89) | NS | | PSBV |
| | • Year effect (P = 0.0111 vs. 0.0033) | MS | NLI | PSBV |
| *Peprilus* spp. | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data | NS | | PI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (11/81 to 3/88) | NS | | PSBV |
| Bothidae | DACI Offshore Diffuser with brine as a covariate (5/80 - 12/95) | NS | | PI |
| | • No brine data | NS | | PI |
| | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (5/81 to 6/89) | NS | | PI |
| *Portunus* spp. | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (4/82 to 12/89) | NS | | PSBV |
| | • Seasonal effect (P = 0.0066 vs. 0.033) | MS | NLI | PSBV |
| | • Year effect (P = 0.0018 vs. 0.0033) | S | NLI | |
| | • Year Season interaction (P = 0.0007 vs. 0.0033) | S | NLI | |
| *Symphurus* spp. | CI Offshore LOOP Terminal Oil Impact with platform oil data as a covariate (5/81 to 9/89) | NS | | PI |

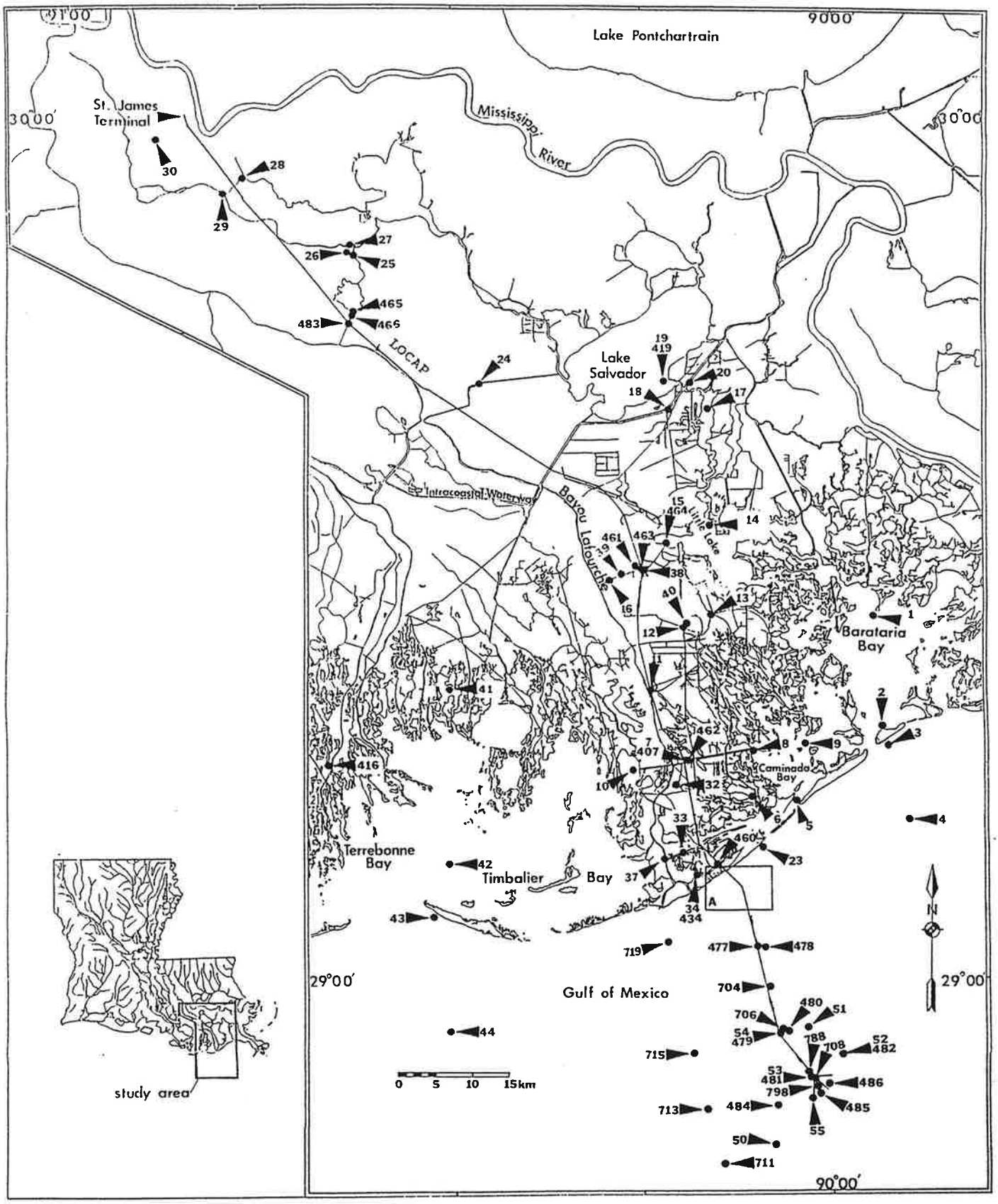


Figure 1. General map of the study area including the alignment of the LOOP (and LOCAP) pipelines. Zooplankton and ichthyoplankton stations are indicated by arrow and number. Box A represents the LOOP brine diffuser area and is shown in detail in Figure 2. (scale = 1:494,000). Modified after Hanifen (1987; Figure 1.2).

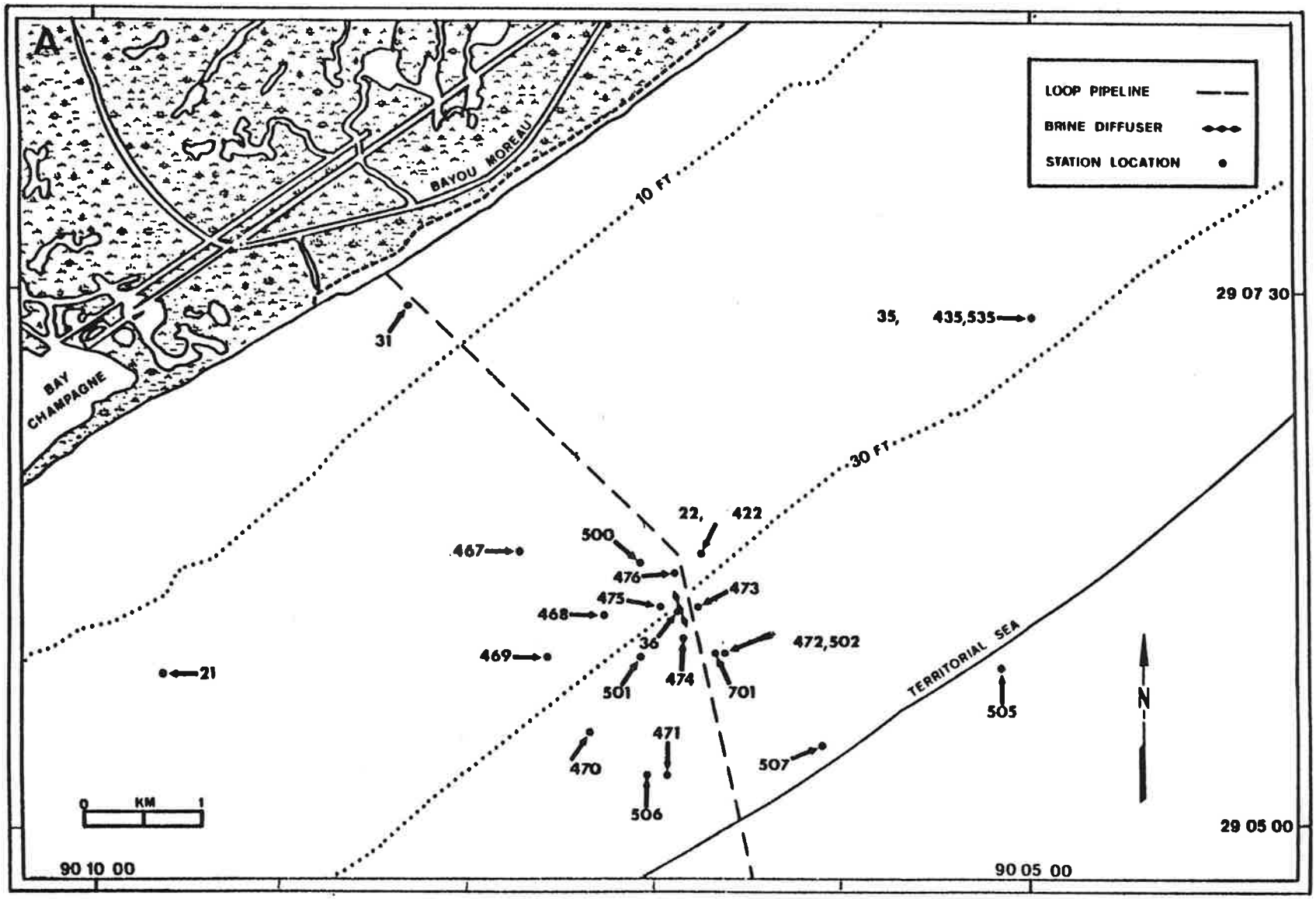


Figure 2. Zooplankton and ichthyoplankton sampling stations in the vicinity of the LOOP brine diffuser (station 36) off the central Louisiana coast. (scale = 1:51,000). Modified after Hanifen (1987; Figure 1.3).



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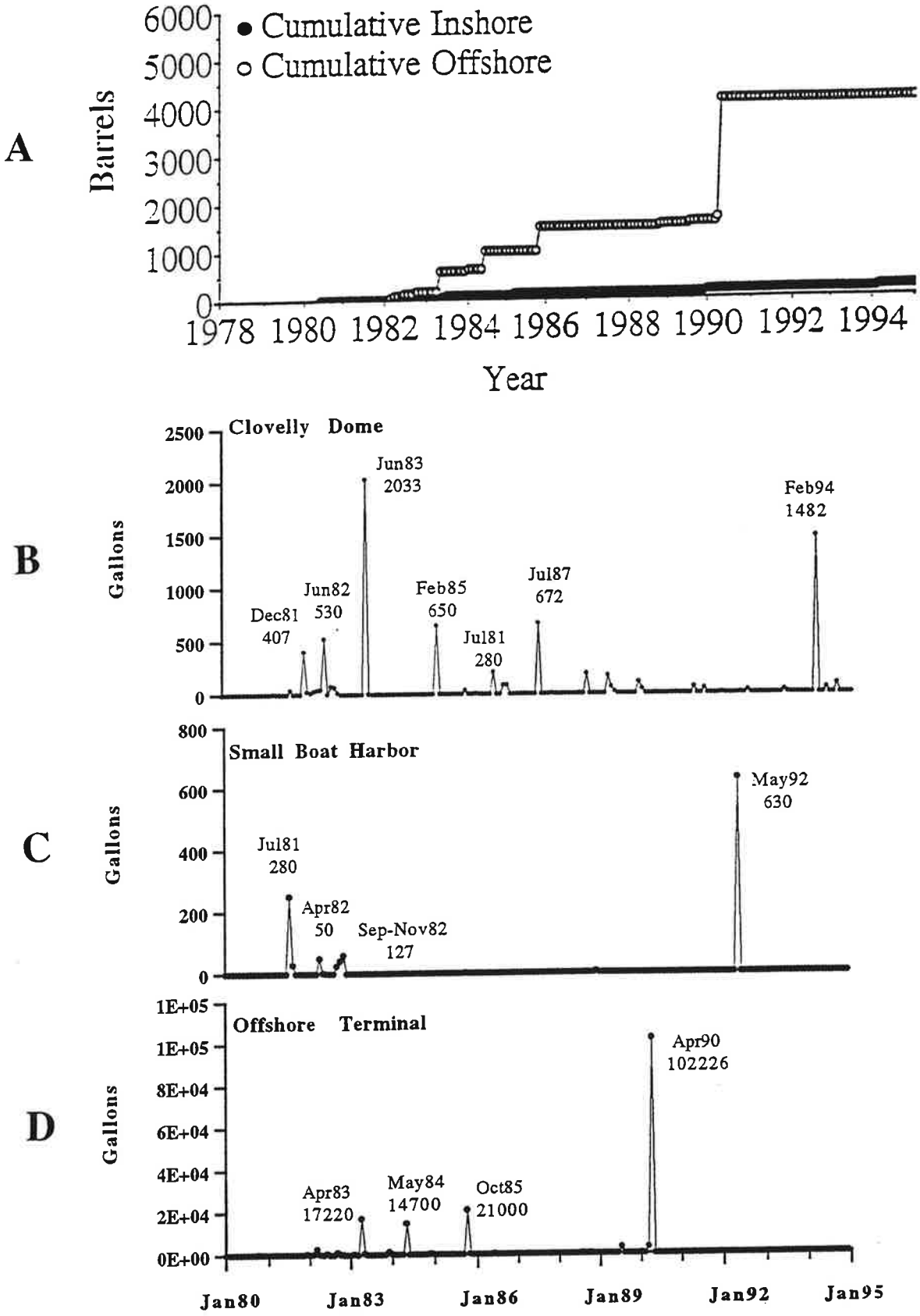


Figure 3. Panel A represents the cumulative release of oil into the environment in barrels by date for inshore and offshore stations. Fifty-seven percent of all the oil spilt during the study period occurred in April 1990 at the offshore terminal. Panels B, C, and D represent LOOP related oil spills in gallons at the Clovelly Salt Dome Storage Facility, the LOOP small boat harbor, and the LOOP offshore platform terminal, respectively.

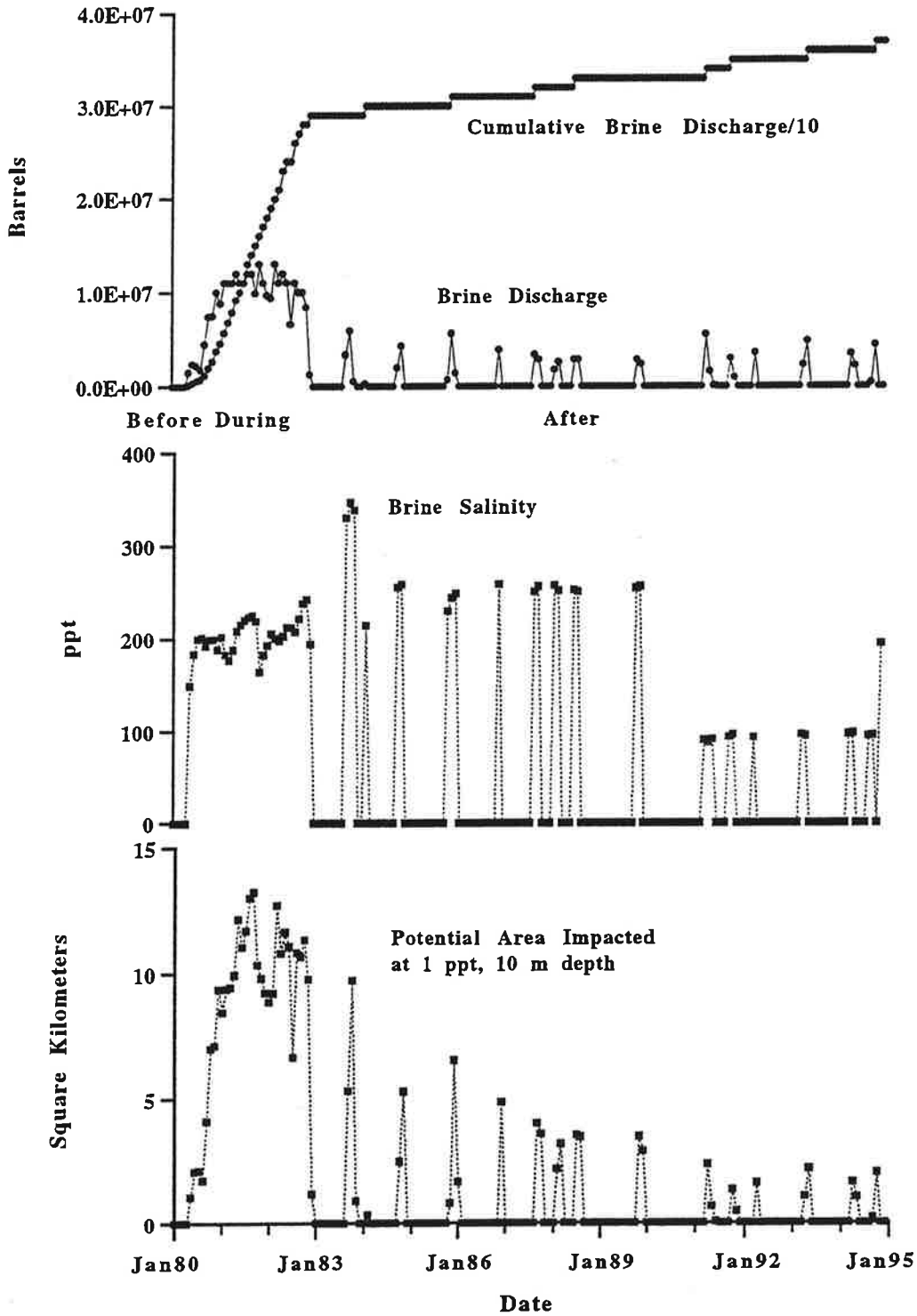


Figure 4. Brine discharge (monthly and cumulative values) in liters and ppt at the nearshore brine diffuser. The bar above the top panel shows the before discharge, maximum discharge, and reduced discharge time periods (A, B, and C respectively). The potential area impacted ($km^2$), based on a 1 ppt increase in a 10 m water column, is shown in the bottom panel.

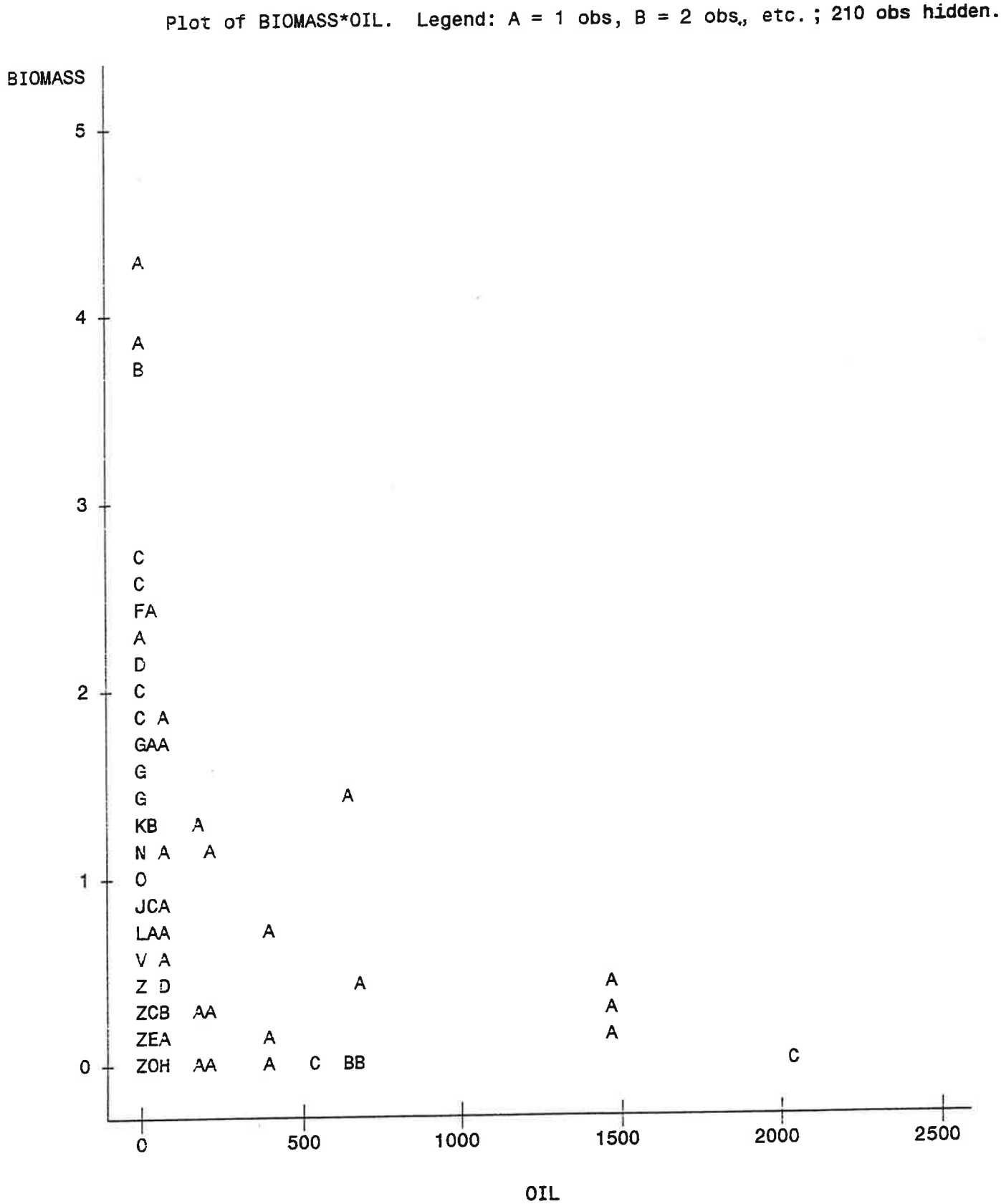


Figure 5. Zooplankton biomass estimates (ml/m$^3$) from impact stations associated with the Clovelly Salt Dome Storage Facility (i.e., stations 15, 16, 38, and 39) plotted against inshore LOOP - related oil spill data (gallons). See Table 4 and 5 for additional information.

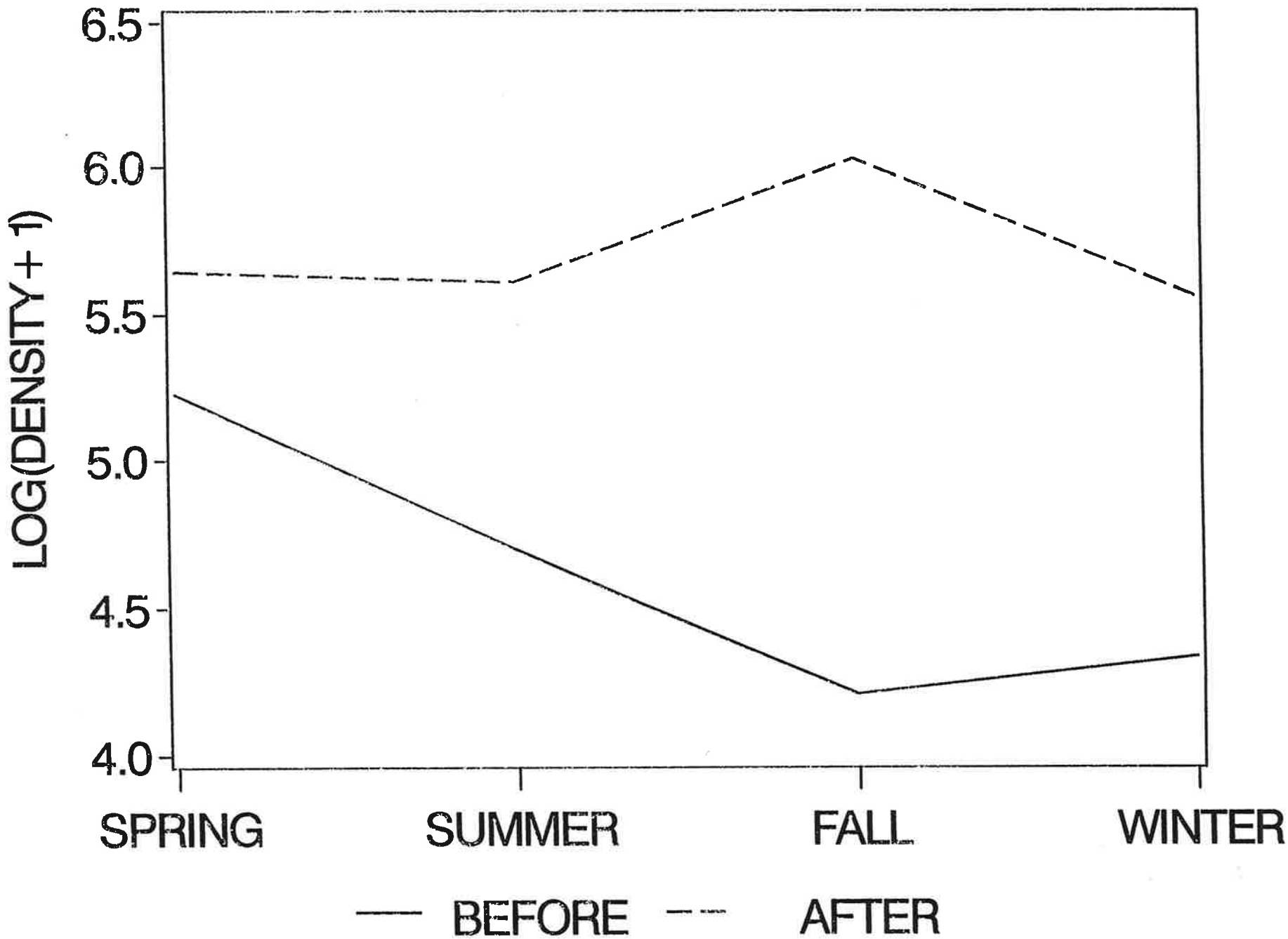


Figure 6. Log - transformed Copepoda mean densities by season for the Before and After time periods from the BACI inshore, reduced time interval, construction impact model. See Tables 4 and 7 and the text for further details.

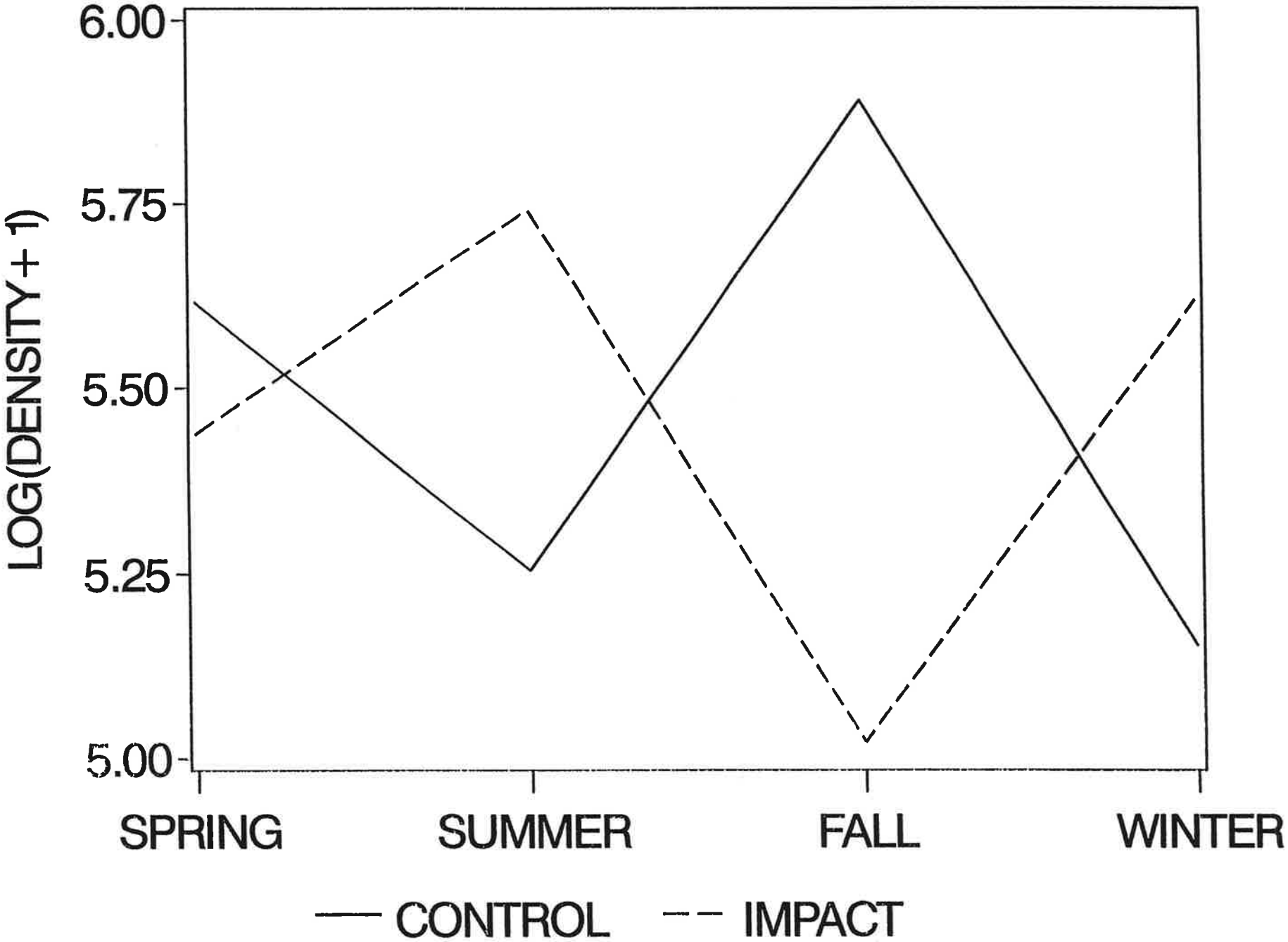


Figure 7. Log - transformed Copepoda mean densities by season for the Control and Impact time periods from the BACI inshore, reduced time period, construction impacts model. See Tables 4 and 7 and the text for further details.



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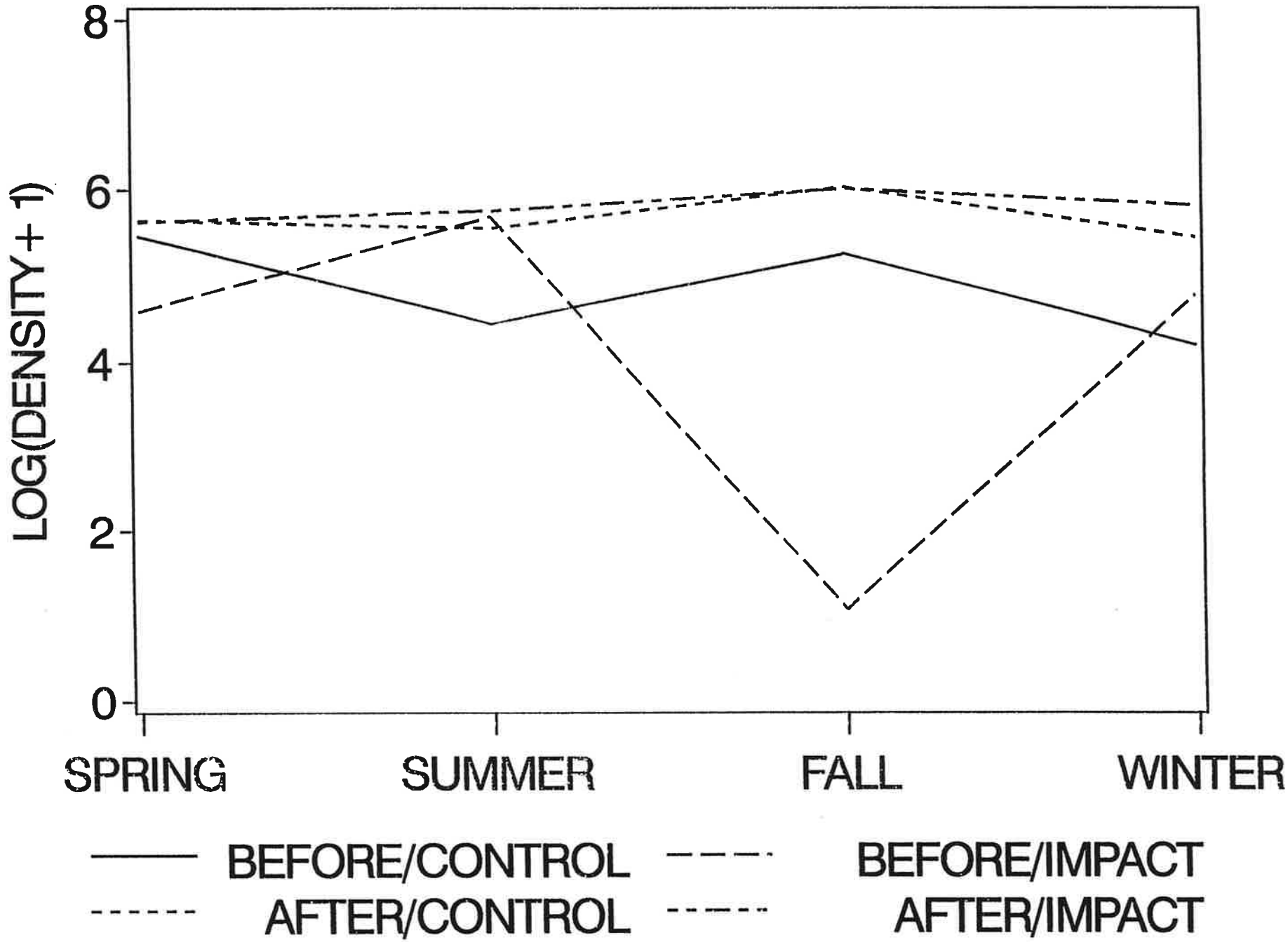


Figure 8. Log-transformed Copepoda mean densities for the Before-After, Control-Impact time periods from the BACI inshore, reduced time period, construction impacts model. See Tables 4 and 7 and the text for further details.



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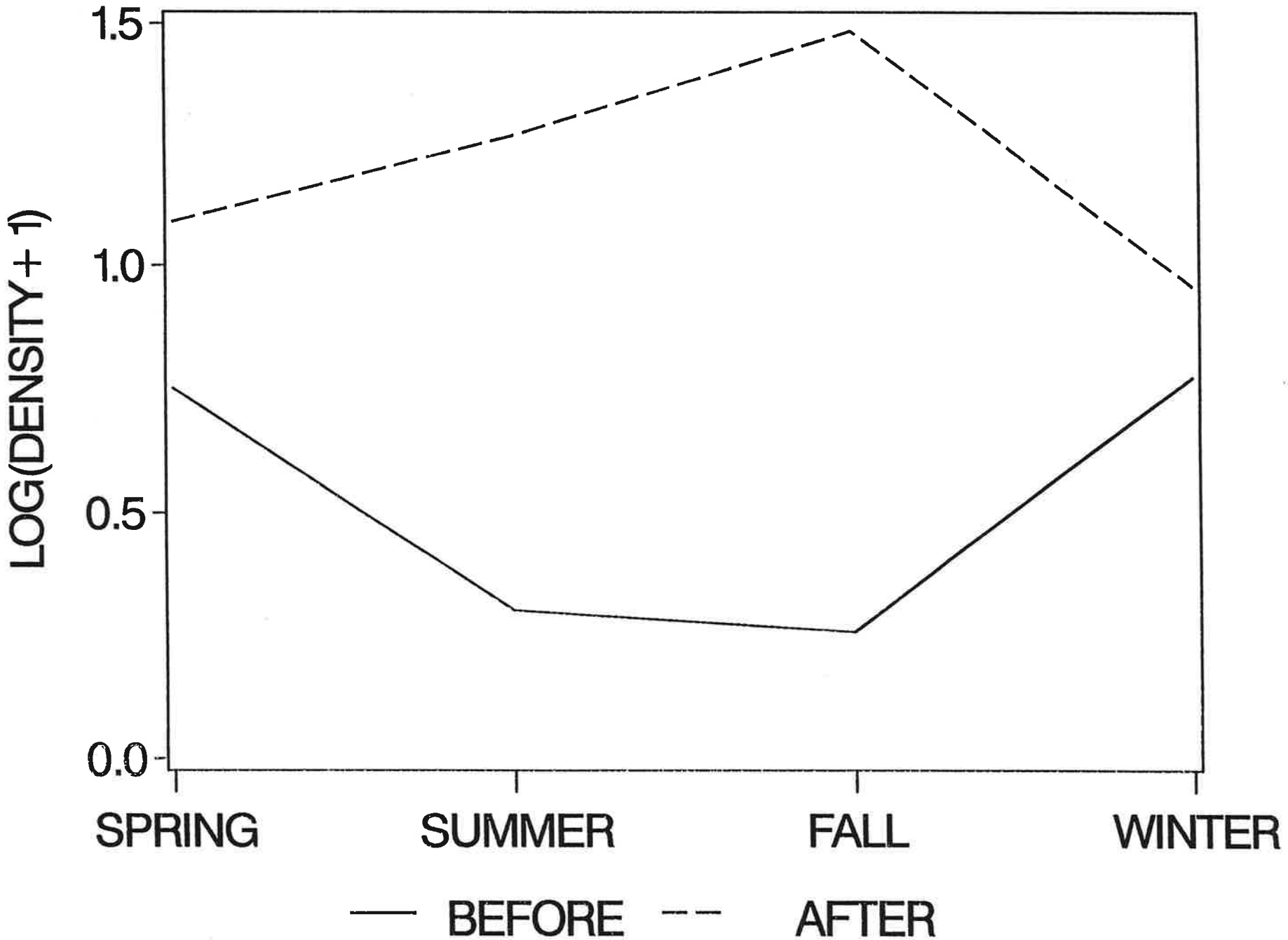


Figure 9. Log-transformed Polychaeta mean densities by season for the Before and After time periods from the BACI inshore, reduced time period, construction impacts model. See Tables 4 and 7 and the text for further details.



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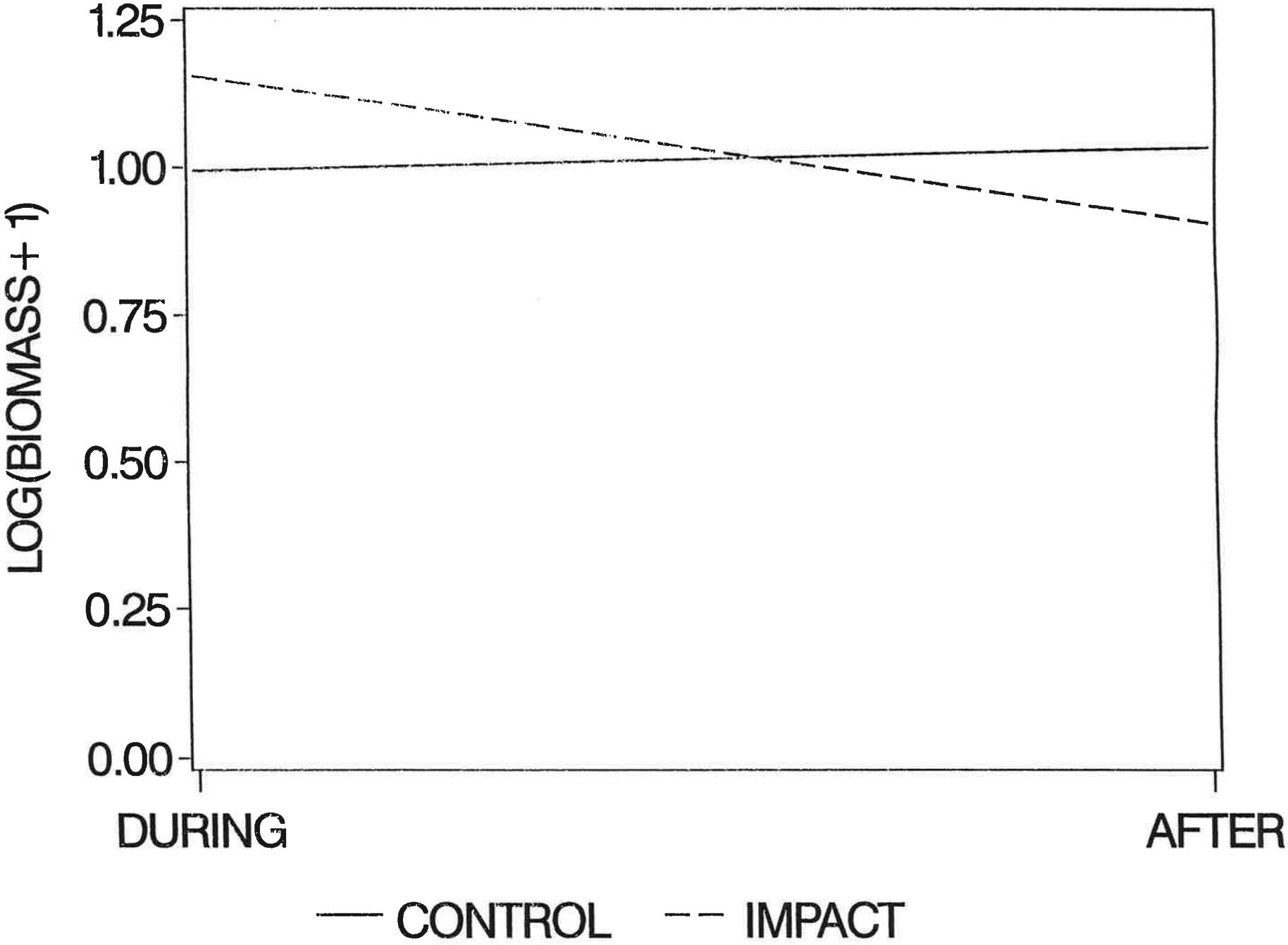


Figure 10. Log-transformed mean zooplankton biomass estimates (displacement volumes) from the During-After and Control-Impact time periods from the DACI inshore, long-term, construction impact model. See Tables 4 and 8 and the text for further details.

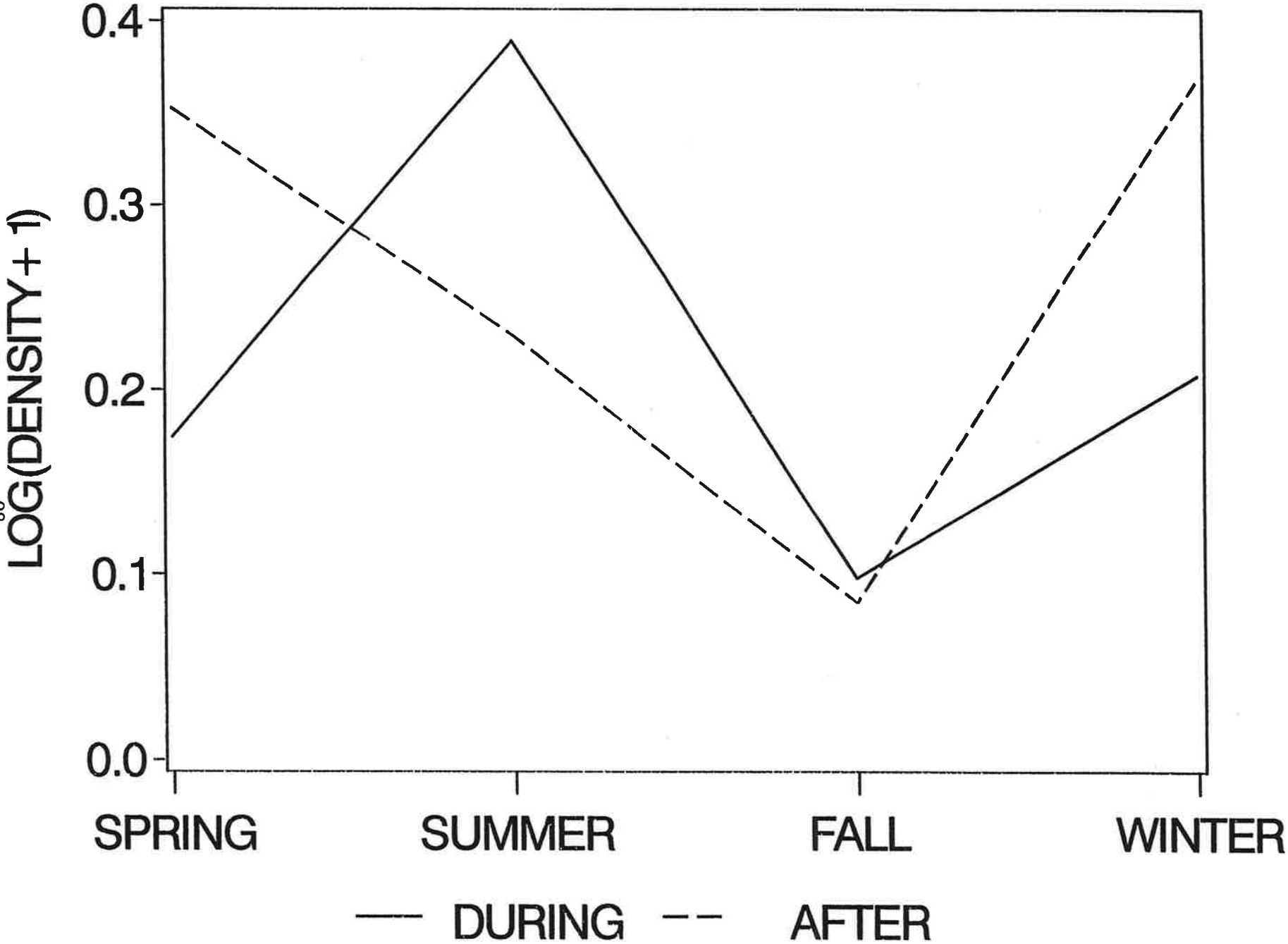


Figure 11. Log-transformed Osteichthyes mean densities by season for the During and After time periods from the DACI inshore, long-term, construction impacts model. See Tables 4 and 8 and the text for further details.



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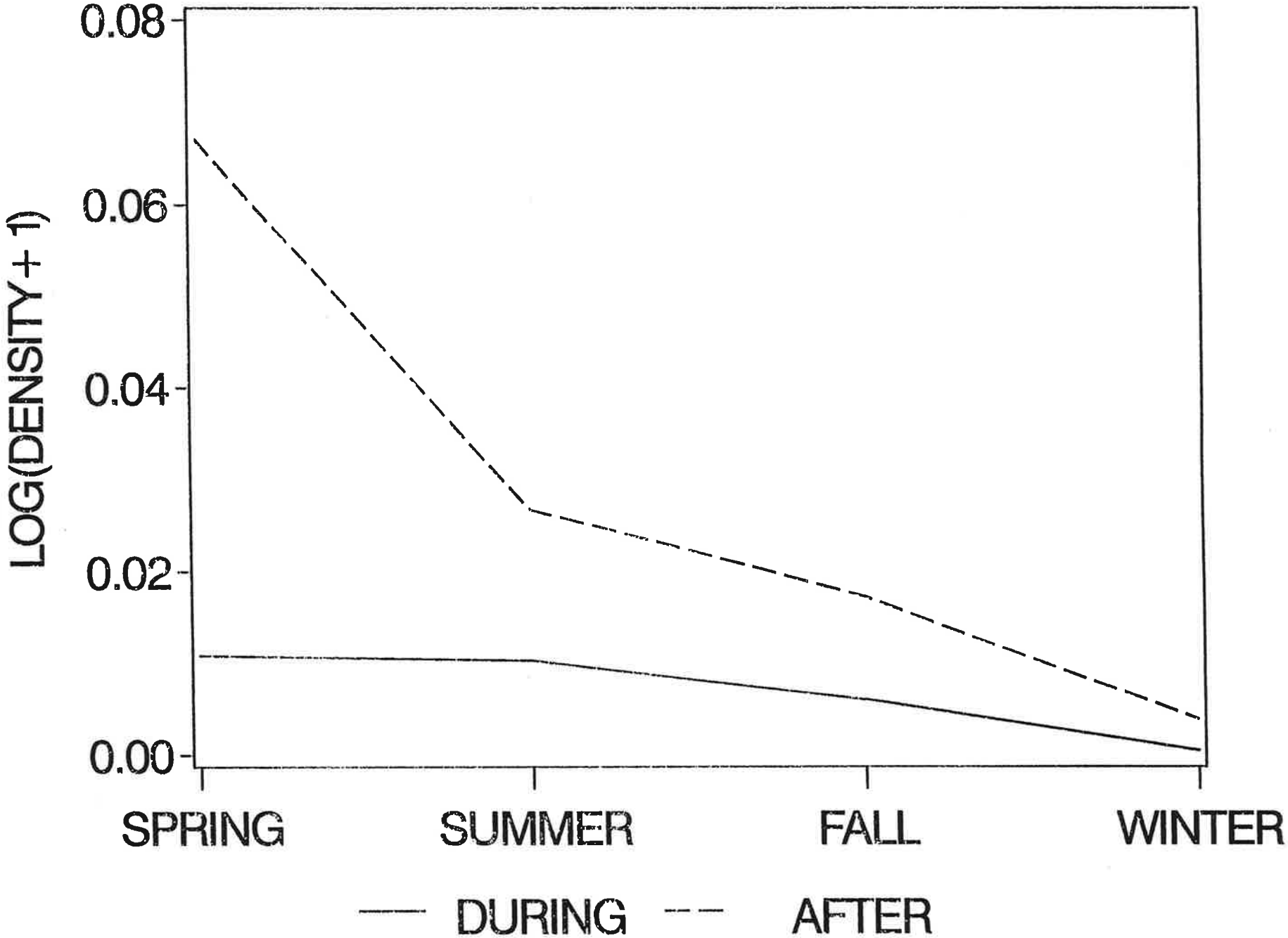


Figure 12. Log-transformed Blennidae mean densities by season for the During and After time periods from the DACI, long-term, offshore Diffuser impacts model. See Tables 4 and 9 and the text for further details.



LOOP1197.sfr

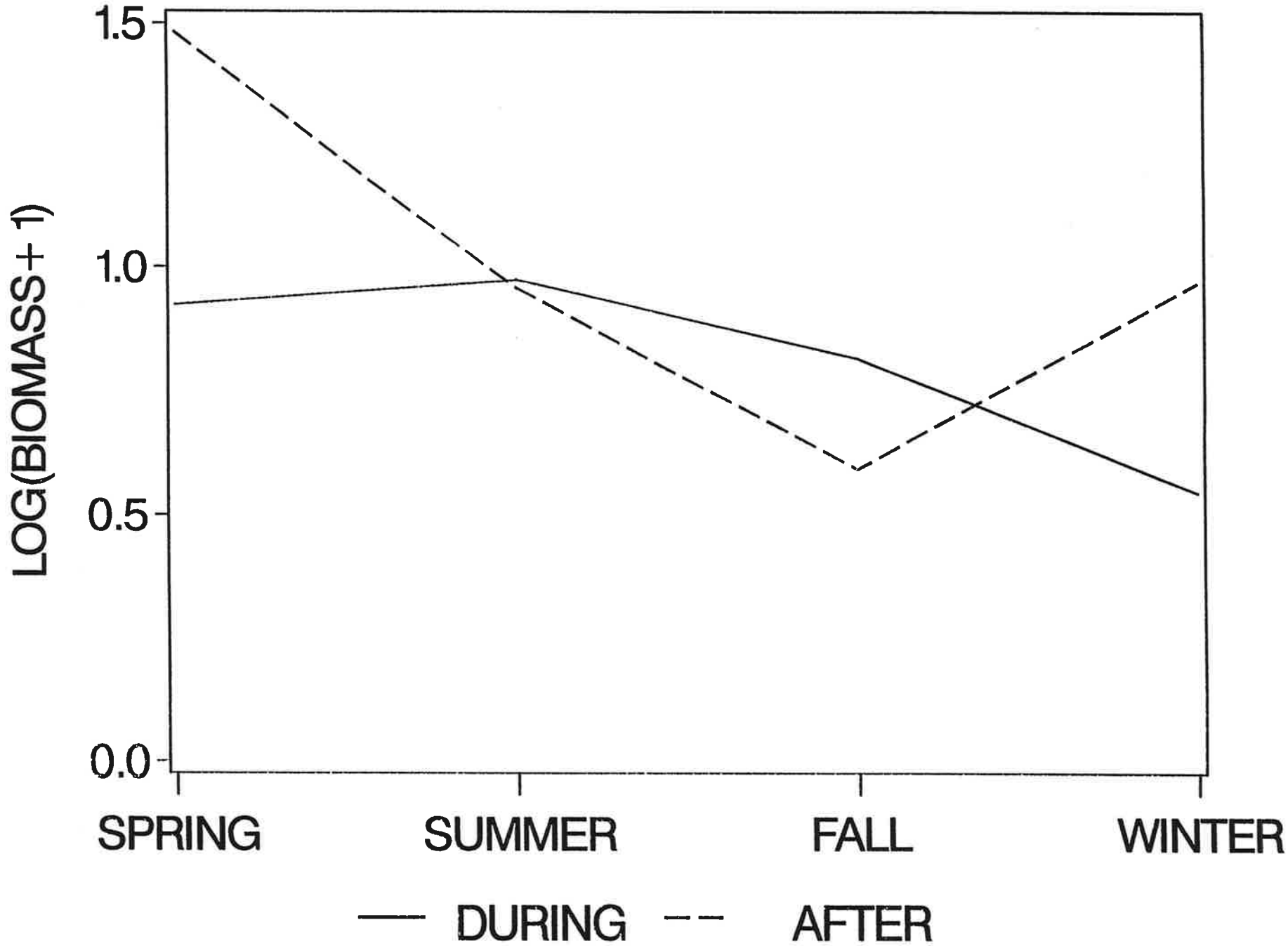


Figure 13. Log-transformed zooplankton biomass estimates (displacement volumes) by season for the During and After time periods from the DACI reduced, long-term, offshore Diffuser impacts model run on HL stations only. See Tables 4 and 10 and the text for further details.



LOOP1197.sft

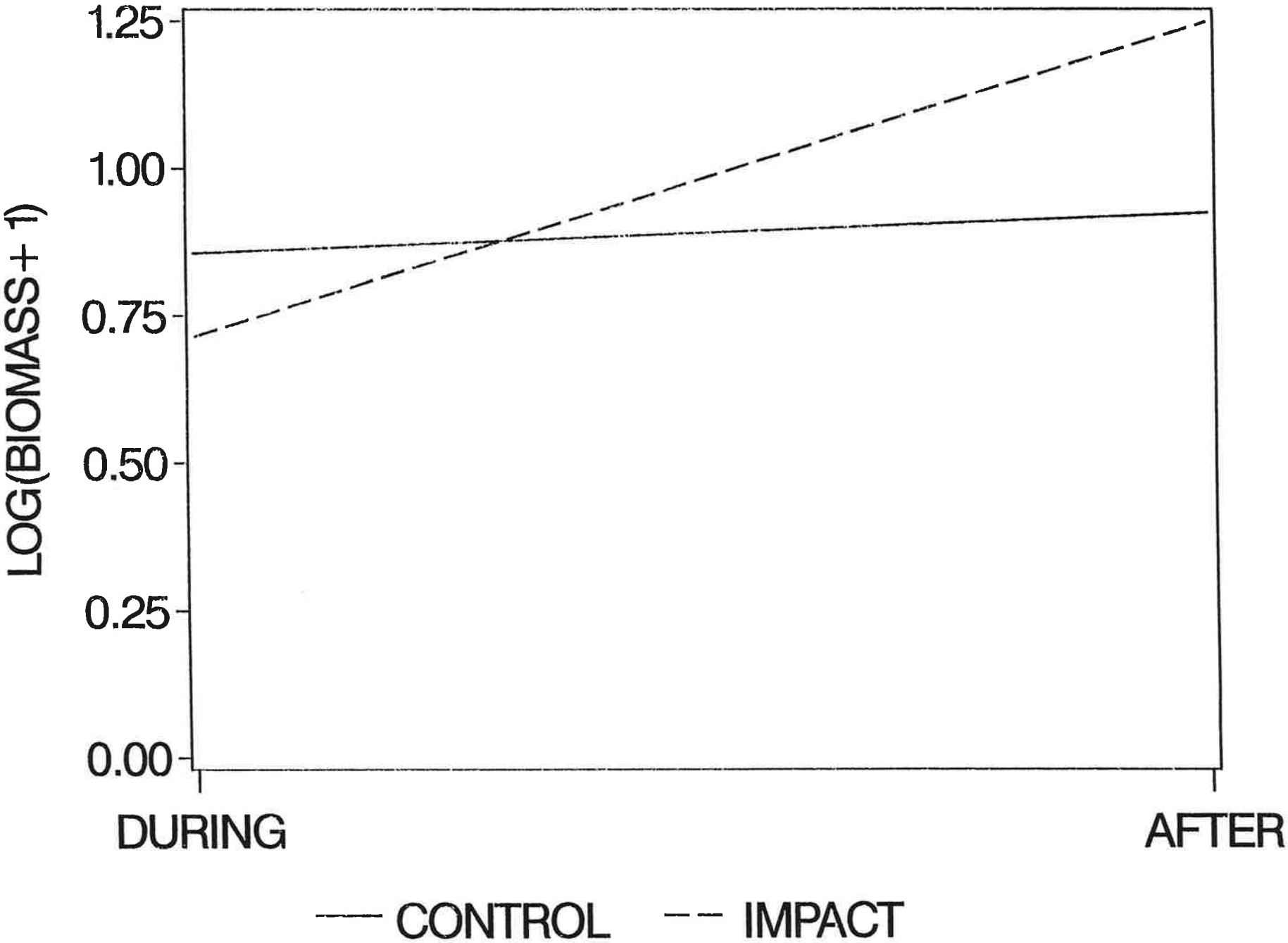


Figure 14. Log-transformed zooplankton biomass estimates (displacement volumes) by season for the Control and Impact stations from the DACI reduced, long-term, offshore Diffuser impacts model run on HL stations only. See Tables 4 and 10 and the text for further details.

Figure 15. Log-transformed mean annual zooplankton biomass (displacement volume) estimates (ml/m$^3$) from May 1981 to December 1994 associated with the LOOP offshore terminal control and impact stations.

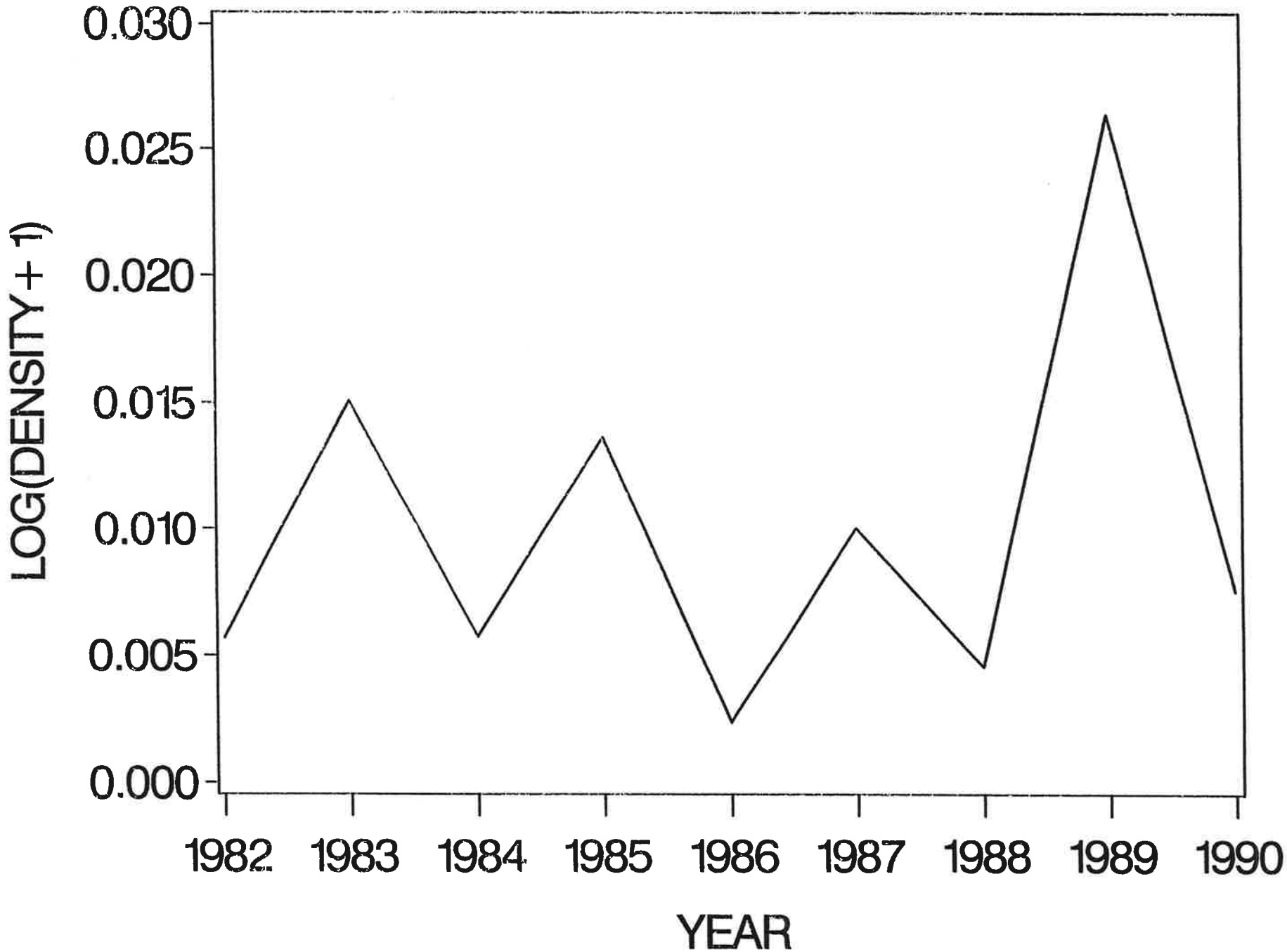


Figure 16. Log-transformed *Penaeus aztecus* mean annual densities (no./m$^3$) from June 1982 to February 1990 associated with the LOOP offshore terminal control and impact stations.

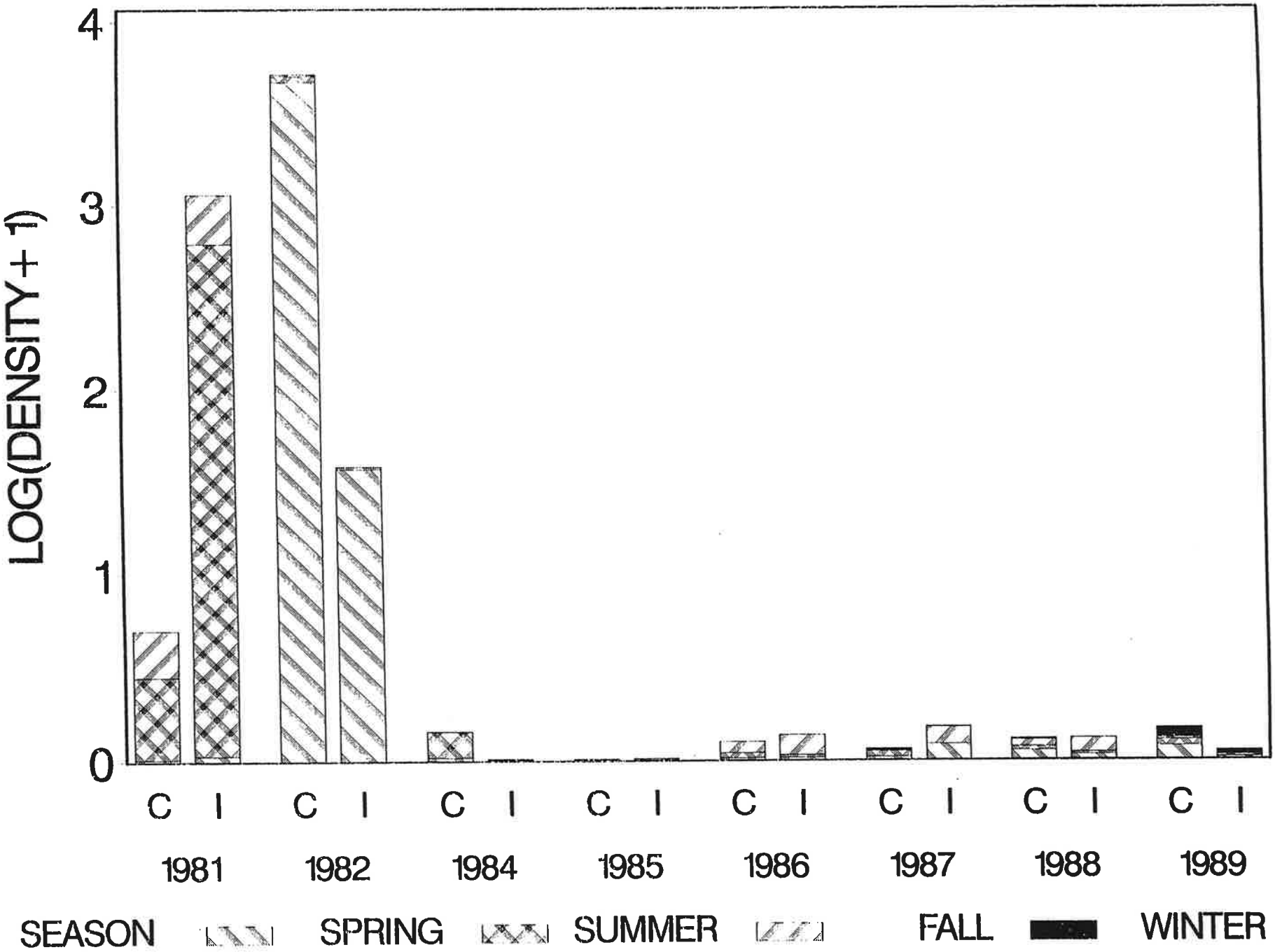


Figure 17. Log-transformed *Callinectes sapidus* mean annual densities (no./m$^3$) by season for control and impact stations from the Control-Impact (CI) offshore LOOP terminal oil impact analysis. The time period tested was from May 1981 to December 1989. Note the absence of 1983 data. See Tables 4 and 11 for further details.

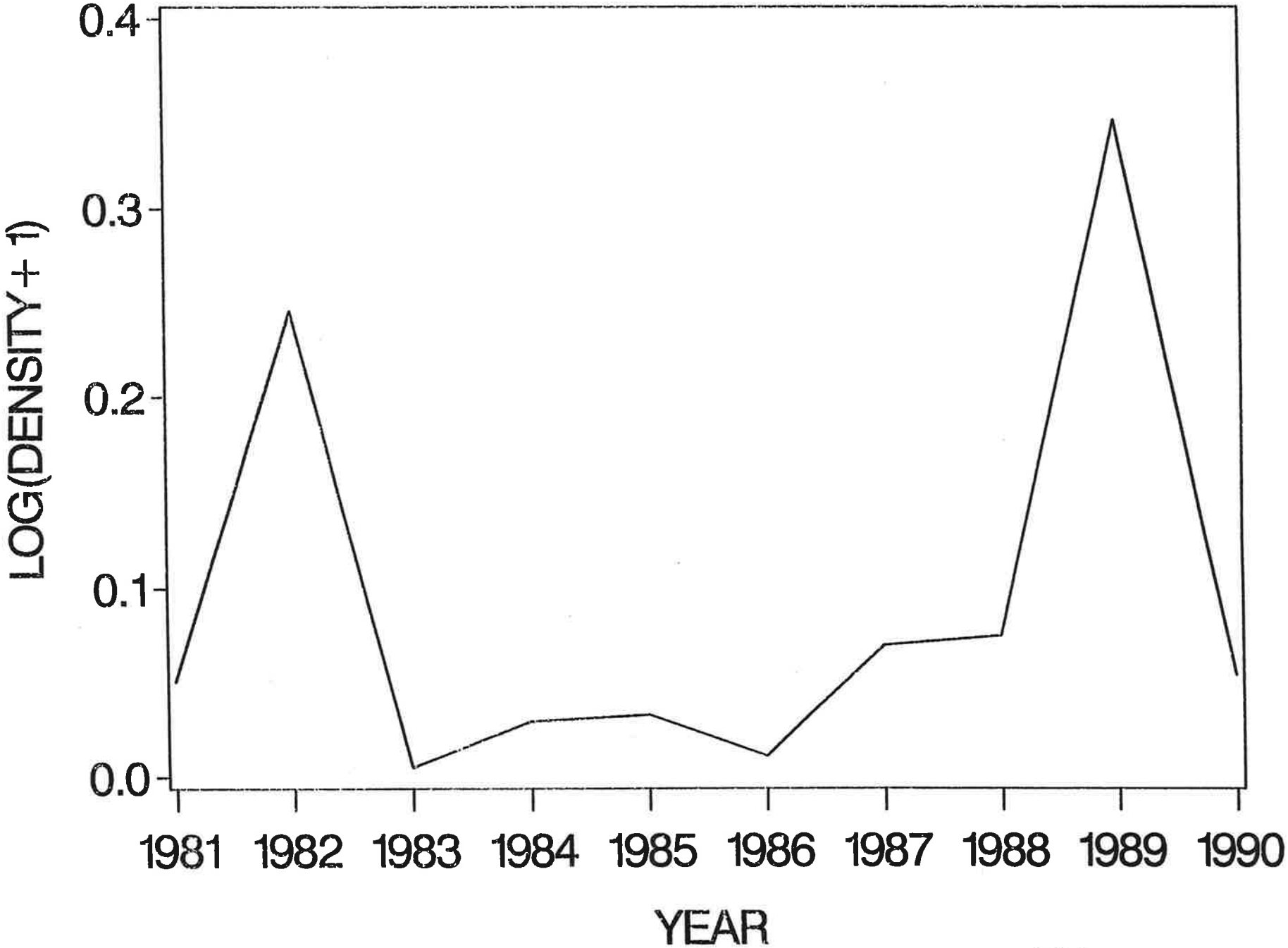


Figure 18. Log-transformed *Callinectes similis* mean annual densities (no./m$^3$) from May 1981 to February 1990 associated with the LOOP offshore terminal control and impact stations.

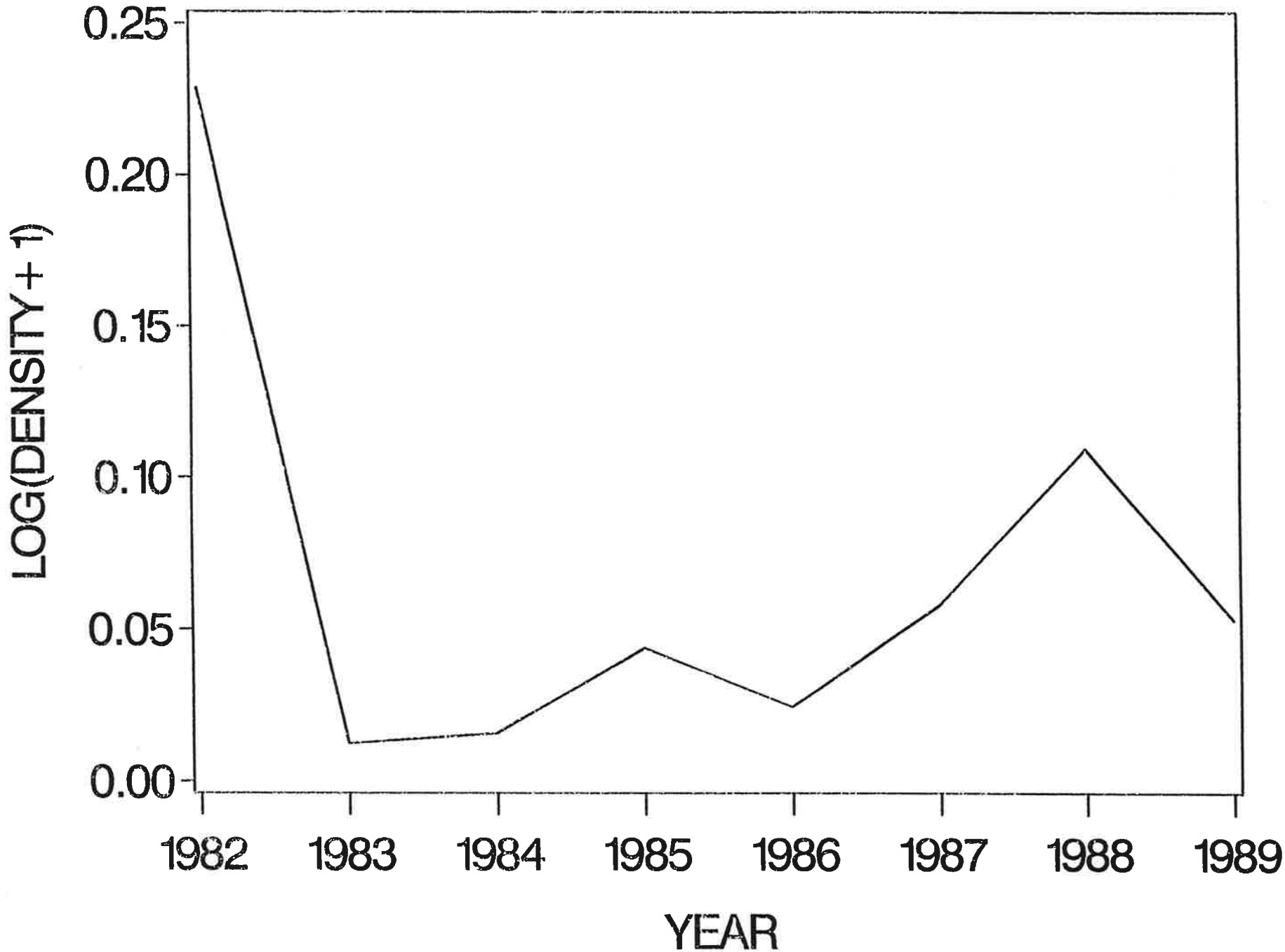


Figure 19. Log-transformed *Portunus* spp. mean annual densities (no./m$^3$) from April 1982 to December 1989 associated with the LOOP offshore terminal control and impact stations.



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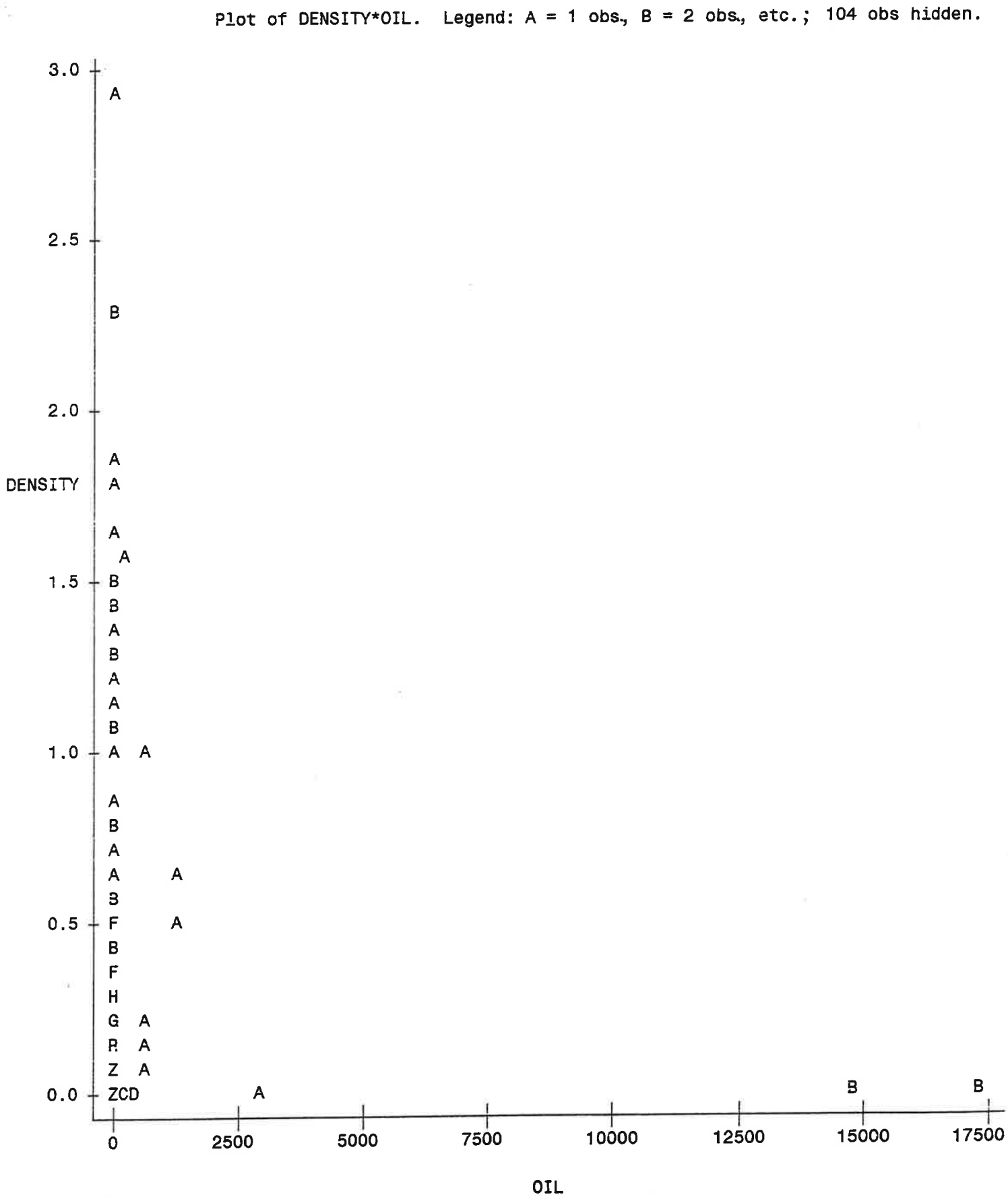


Figure 20. Log-transformed *Anchoa* spp. densities (no./m$^3$) from impact stations associated with the LOOP offshore terminal (i.e., stations 53 and 55) plotted against offshore LOOP - related oil spill data (gallons).

Figure 21. Log-transformed *Anchoa* spp. mean annual densities (no./m$^3$) from June 1981 to September 1989 associated with LOOP offshore terminal control and impact stations.



LOOP1197.sf

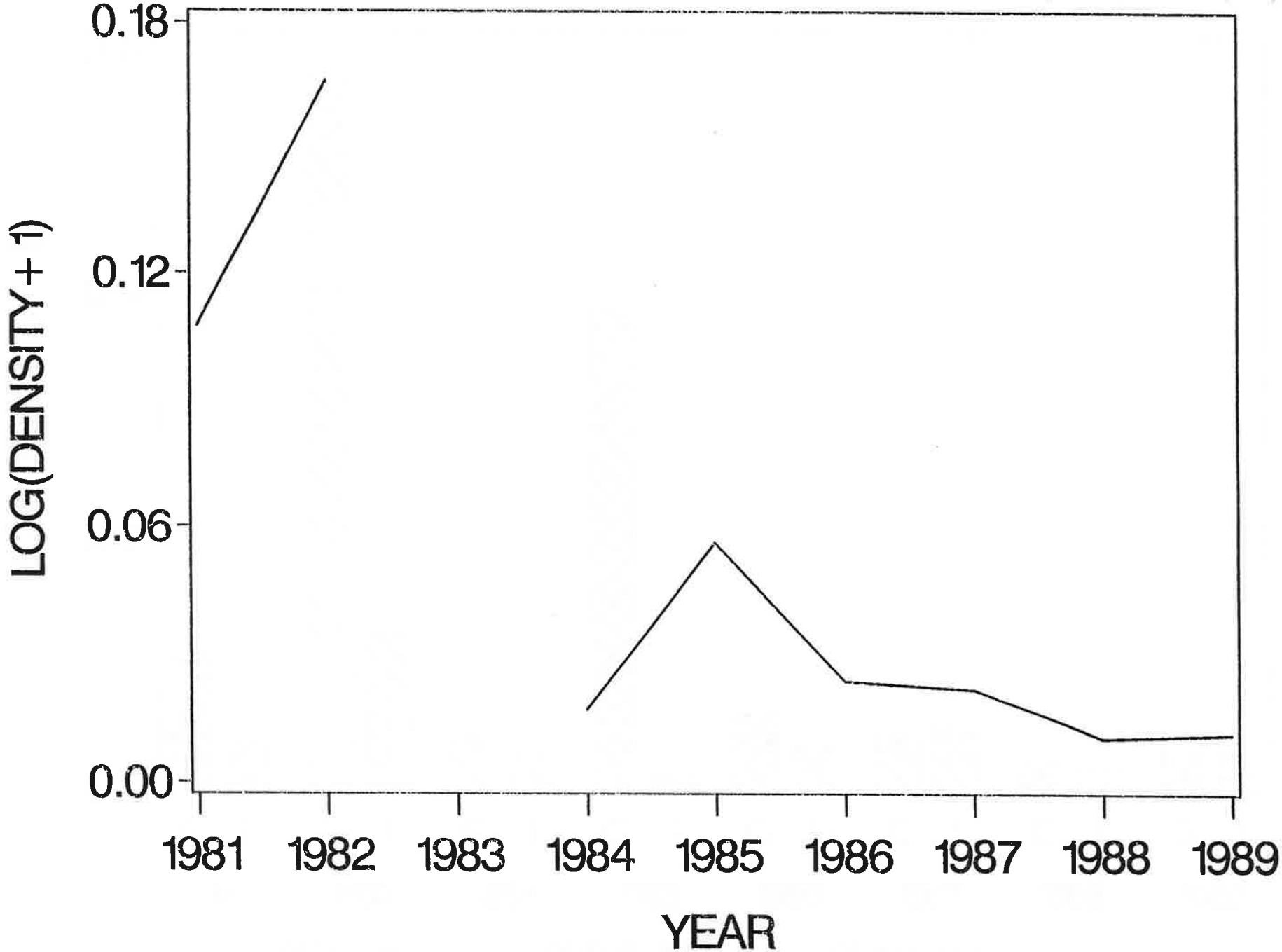


Figure 22. Log-transformed *Chloroscombrus chrysurus* mean annual densities (no./m$^3$) from August 1981 to September 1989 associated with LOOP offshore terminal control and impact stations. Note absence of 1983 data.



LOOP1197.sft

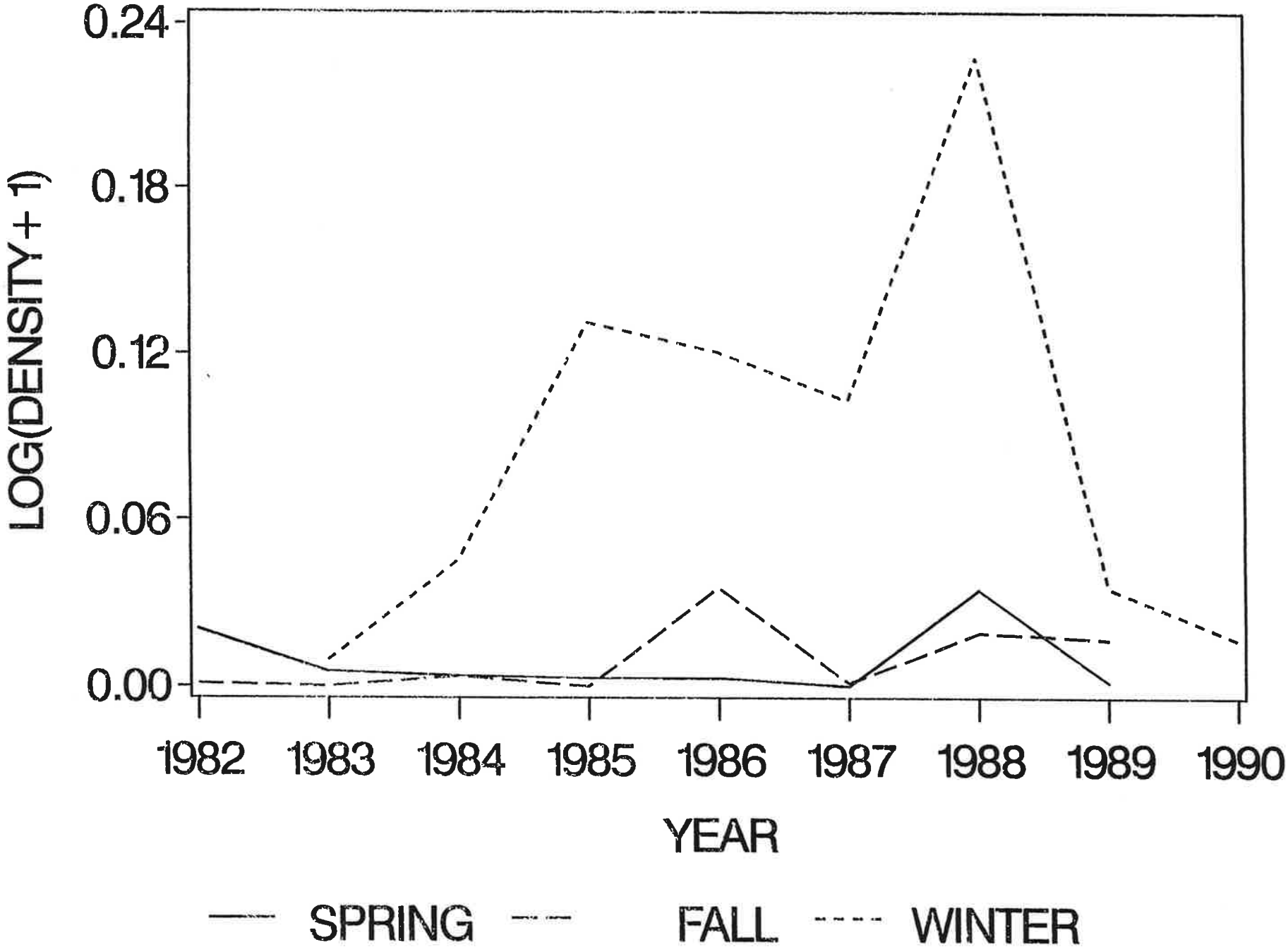


Figure 25. Log-transformed Myctophidae mean annual densities (no./m$^3$) by season from May 1982 to February 1990 associated with the LOOP offshore terminal control and impact stations. Note absence of the summer season.

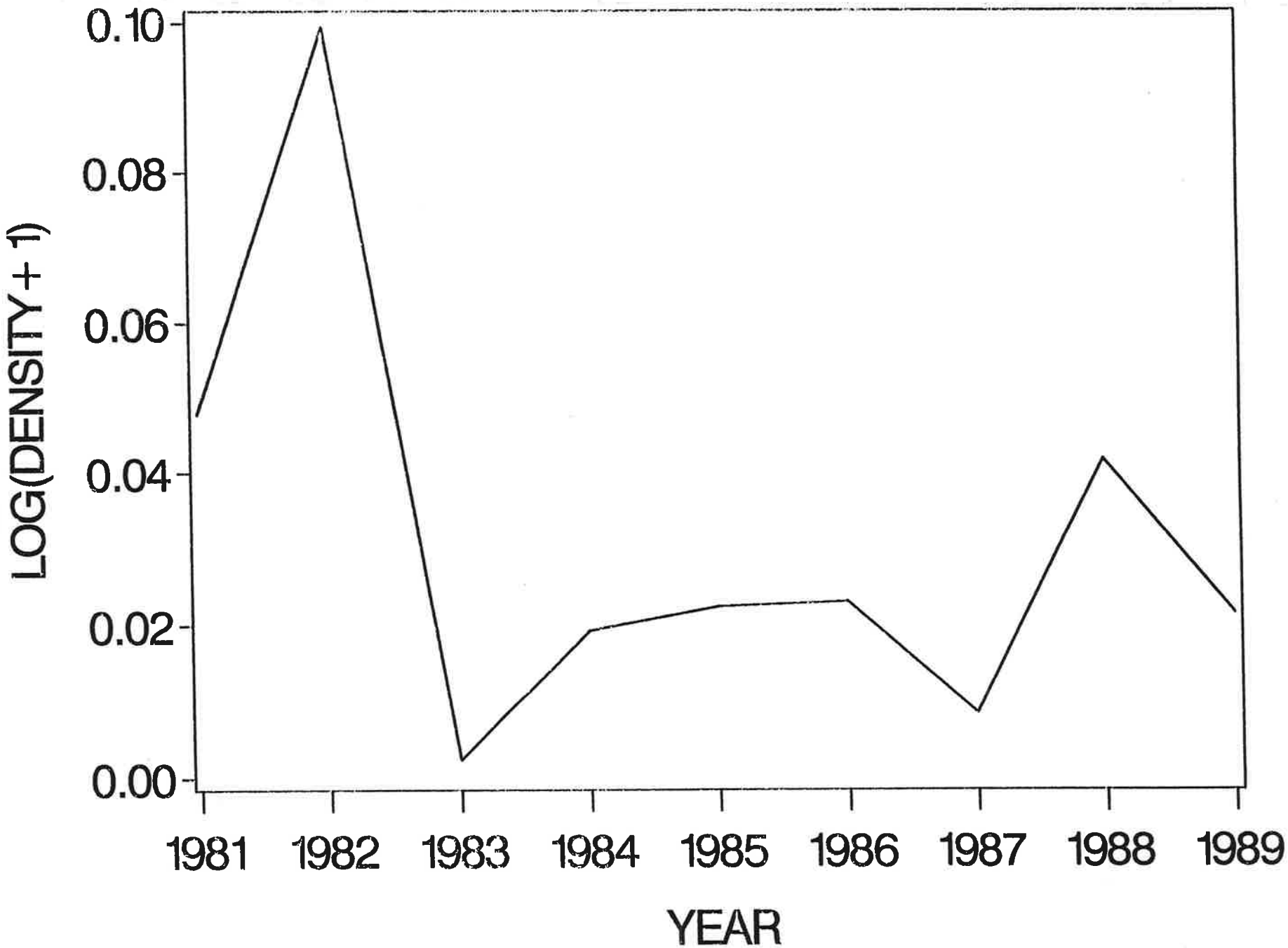


Figure 26. Log-transformed Scombridae mean annual densities (no./m$^3$) from August 1981 to September 1989 associated with the LOOP offshore terminal control and impact stations.

# APPENDIX

Table A-1. List of reports produced for superport planning (after Sasser et al. 1982).

| Year | Title | Comment |
|---|---|---|
| 1972 | LOOP feasibility study | LOOP's Engineering Feasibility Study |
| 1972 | A Superport for Louisiana | Superport Task Force Report |
| 1972 | LSU Superport Study #1 | Requested by Superport Task Force |
| 1972 | LSU Superport Study #2 | Requested by National Sea Grant Program |
| 1973 | LSU Superport Study #3 | Requested by LOTA to formulate EPP |
| 1973 | LSU Superport Study #4 | Requested by LOTA to formulate EPP |
| 1974 | Alternate Site Location Evaluation | Prepared by Dames and Moore for LOOP, Inc. |
| 1976 | Environmental Baseline Studies Vols. 1–4 | Prepared by LSU for LOOP, Inc. |
| 1976 | Environmental Impact Study | US Department of Transportation |

Table A-2. Monthly mean densities (with the number of positive samples and standard deviation in parenthesis) for zooplankton biomass (ml/m$^3$; settled and displacement volumes) and for zooplankton taxa (no./m$^3$) collected with a 0.5 m, 0.153 - mm mesh net between February 1978 and December 1995 during the LOOP Environmental Monitoring Project. Taxonomic order within table was determined by the National Oceanographic Data Center (NODC) code.

| | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE |
|---|---|---|---|---|---|---|
| Settled Volume | 5.06(201;14.36) | 5.29(206;13.3) | 4.69(186;9.72) | 30.68(205;349.76) | 2.99(226;6.56) | 2.34(228;4.41) |
| Displacement Volume | 1.8(186;4.78) | 2(177;4.4) | 2.18(164;4.32) | 6.99(158;59.08) | 1.75(177;5.95) | 0.82(187;1.87) |
| VOLVOX | - | - | 1.84(2;1.62) | - | - | - |
| NOCTILUCA SCINTILLANS | 186.1(4;291.8) | 45.6(10;79.47) | 71263(24;222855) | 266.2(10;314.9) | 45778(1;.) | 580(1;.) |
| CERATIUM | - | - | - | - | - | 193.3(2;240.1) |
| PROTOZOA | 392.7(6;728.1) | 5.47(3;4.93) | 925(3;1581) | 1.29(3;1.18) | 67.3(3;42.8) | 1105(1;.) |
| DINOFLAGELLIDA | 8.22(5;6.7) | 2.68(1;.) | 12.18(2;9.9) | 17.08(5;22.92) | 635(6;677) | 96.8(3;75.3) |
| FORAMINIFERIDA | 77.6(18;131.5) | 72.8(11;191.4) | 2.19(1;.) | 46.97(3;39.62) | 65(6;112) | 239.9(2;100.3) |
| RADIOLARIA | - | - | - | - | 9.38(1;.) | - |
| TINTINNINA | - | 0.97(2;1.09) | - | 26.37(1;.) | 103.5(2;35.8) | 75.6(6;64.6) |
| PORIFERA(Larva) | - | - | - | - | - | - |
| CNIDARIA | 5.01(4;9.8) | 0.06(1;.) | 26.07(2;27.34) | 12.84(5;6.88) | 34.3(4;33.33) | 51.3(3;26) |
| CNIDARIA(Medusa) | 1.8(1;.) | - | - | - | - | - |
| HYDROZOA | 0.36(2;0.21) | - | 27.4(2;18.96) | 8.81(3;7.87) | 6.05(3;3.2) | 17.97(1;.) |
| HYDROZOA(Medusa) | - | 0.37(1;.) | 3.7(5;3.49) | 18.2(2;24.23) | 5.74(5;7.25) | - |
| HYDROZOA(Colony) | - | 2.9(1;.) | - | - | - | - |
| ANTHOMEDUSAE(Medusa) | - | - | - | 0.05(1;.) | - | - |
| NEMOPSIS BACHEI | - | 0.14(1;.) | - | - | - | - |
| EUPHYSORA GRACILIS(Medusa) | - | - | 0.25(1;.) | - | - | - |
| OBELIA | - | - | - | - | - | - |
| PHIALIDIUM LANGUIDUM(Medusa) | - | - | - | 0.05(1;.) | - | - |
| LIRIOPE TETRAPHYLLA | - | - | - | 1.23(4;1.09) | 8.37(4;14.24) | 1.77(1;.) |
| LIRIOPE TETRAPHYLLA(Medusa) | - | - | - | - | 77.4(1;.) | - |
| SIPHONOPHORA | 0.78(3;1) | 1.29(1;.) | 0.87(1;.) | 26.72(4;52.86) | 8.57(2;1.2) | 134.8(1;.) |
| MUGGIAEA | - | - | - | - | - | 2.66(1;.) |
| ABYLOPSIS | - | - | - | - | - | - |
| CTENOPHORA(Larva) | - | - | - | 0.83(1;.) | - | - |
| CTENOPHORA | 10.83(1;.) | - | 3.37(1;.) | 0.74(5;0.96) | 0.21(1;.) | - |
| PLEUROBRACHIA | - | - | - | - | - | - |
| MNEMIOPSIS MECRADYI | - | - | - | - | - | - |
| BEROE OVATA | 0.11(1;.) | - | - | 0.4(1;.) | - | - |
| PLATYHELMINTHES(Larva) | - | - | 0.93(1;.) | - | - | - |
| PLATYHELMINTHES(Juvenile) | - | - | 19.75(1;.) | - | - | - |
| PLATYHELMINTHES | - | 1.58(3;0.76) | 3.37(1;.) | - | - | - |
| ROTIFERA | 157.3(3;118.1) | 35.08(6;39.8) | 26.01(4;30.05) | 17.21(4;13.19) | 253.1(5;434.9) | 465.6(6;710.4) |
| ROTIFERA(Colony) | - | - | - | - | - | 282.3(1;.) |
| BRACHIONIDAE | - | - | 76(3;120.8) | 6.54(1;.) | - | 20.91(1;.) |
| NEMATODA(Larva) | - | - | - | - | - | 0.05(1;.) |
| NEMATODA | 55.9(3;82.7) | 3.89(3;1.63) | 26.97(4;7.41) | 9.52(2;9.57) | - | 36.03(2;3.98) |
| NEMATOMORPHA(Larva) | - | - | - | 46.63(1;.) | - | - |

Table A-2 continued.

| | JULY | AUGUST | SEPTEMBER | OCTOBER | NOVEMBER | DECEMBER |
|---|---|---|---|---|---|---|
| Settled Volume | 3.52(224;7.81) | 3.35(204;5.99) | 2.41(193;3.33) | 2.54(178;3) | 3.3(206;5.94) | 2.93(198;6.46) |
| Displacement Volume | 1.2(168;2.52) | 1.07(177;1.98) | 0.99(181;1.71) | 1.32(160;3.51) | 1.44(182;2.79) | 1.35(171;2.78) |
| VOLVOX | - | - | - | - | - | - |
| NOCTILUCA SCINTILLANS | - | - | - | - | 1194(1;.) | - |
| CERATIUM | - | - | 6057(10;12869) | 160.3(3;126.1) | - | - |
| PROTOZOA | 75(3;71.1) | - | 128.4(3;214) | - | 315.2(2;127.5) | - |
| DINOFLAGELLIDA | - | 11556(1;.) | 17926(9;27141) | 567(13;1021) | 132.7(2;47.3) | 503(4;914) |
| FORAMINIFERIDA | 8.4(2;10.58) | 97(4;183) | 1032(15;3925) | 31.79(6;32.87) | 83.4(12;94.7) | 59(11;30.2) |
| RADIOLARIA | - | 8.78(1;.) | 160.7(1;.) | - | - | - |
| TINTINNINA | - | 1997(3;3358) | 2165(17;6496) | 207.1(2;53.5) | - | 83.1(2;112.8) |
| PORIFERA(Larva) | - | - | 41.97(3;70.57) | - | - | - |
| CNIDARIA | 58(4;53.7) | 51(7;59.4) | 38.03(18;52.99) | 41.58(14;66.81) | 120.4(2;169.1) | 55.7(4;67.4) |
| CNIDARIA(Medusa) | - | - | - | - | - | - |
| HYDROZOA | 7.98(6;9.34) | 2.03(4;1.1) | 167.3(11;367.4) | 28.8(7;42.23) | 12.48(3;19.28) | 0.64(1;.) |
| HYDROZOA(Medusa) | - | - | - | - | - | - |
| HYDROZOA(Colony) | - | - | - | - | - | - |
| ANTHOMEDUSAE(Medusa) | - | - | - | - | - | - |
| NEMOPSIS BACHEI | - | 1.44(1;.) | - | 5.67(1;.) | - | - |
| EUPHYSORA GRACILIS(Medusa) | - | - | - | - | - | - |
| OBELIA | - | - | - | 2.84(1;.) | - | - |
| PHIALIDIUM LANGUIDUM(Medusa) | - | - | - | - | - | - |
| LIRIOPE TETRAPHYLLA | 2.6(4;2.63) | 434.7(7;1128.5) | 11.47(7;8.69) | 70.2(5;68.7) | 0.97(1;.) | - |
| LIRIOPE TETRAPHYLLA(Medusa) | - | - | - | - | - | - |
| SIPHONOPHORA | 55.9(1;.) | - | 23.25(2;3) | 432.8(6;988.5) | 5.62(1;.) | 16.26(5;23.46) |
| MUGGIAEA | - | - | - | - | - | - |
| ABYLOPSIS | - | - | - | - | - | 1.18(1;.) |
| CTENOPHORA(Larva) | - | - | - | - | - | - |
| CTENOPHORA | 5.6(10;15.49) | - | 0.44(1;.) | 209.3(3;320.5) | 6.98(3;11.94) | 5.84(2;2.28) |
| PLEUROBRACHIA | - | 0.17(1;.) | 1.41(2;1.73) | 8.42(2;10.37) | - | - |
| MNEMIOPSIS MECRADYI | - | - | - | 2.84(1;.) | - | 0.92(1;.) |
| BEROE OVATA | - | - | - | - | - | - |
| PLATYHELMINTHES(Larva) | - | - | - | - | - | - |
| PLATYHELMINTHES(Juvenile) | - | - | - | - | - | - |
| PLATYHELMINTHES | - | 1.92(2;1.62) | 0.27(2;0.3) | - | - | - |
| ROTIFERA | 521(5;898) | 10976(5;21053) | 2.91(2;1.34) | - | - | 78.7(1;.) |
| ROTIFERA(Colony) | - | - | - | - | - | - |
| BRACHIONIDAE | - | - | - | - | - | - |
| NEMATODA(Larva) | - | - | - | - | - | - |
| NEMATODA | 42.85(2;36.41) | 4.58(1;.) | 3.09(2;4.3) | 74.4(2;102.8) | - | - |
| NEMATOMORPHA(Larva) | - | - | - | - | - | - |

Table A-2 continued.

| | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE |
|---|---|---|---|---|---|---|
| ANNELIDA(Larva) | 17.93(1;.) | - | - | - | 6.45(1;.) | - |
| POLYCHAETA(Juvenile) | 21.69(20;17.47) | 1.05(3;1.17) | 6.32(1;.) | - | - | - |
| POLYCHAETA | - | - | - | - | - | - |
| POLYCHAETA(Trochophore larva) | 11.81(14;20.83) | 37.17(21;71.96) | 51.7(54;83.6) | 46.85(55;64.62) | 53.5(56;80) | 53.9(34;62.2) |
| POLYCHAETA(Mitaria) | - | 0.18(1;.) | - | - | - | - |
| ALCIOPIDAE | - | - | - | - | - | - |
| TYPHLOSCOLECIDAE(Larva) | - | - | - | - | - | - |
| TYPHLOSCOLECIDAE | - | - | - | - | 8.99(1;.) | - |
| TOMOPTERIS | 6.9(1;.) | - | - | 0.72(3;0.16) | 8.99(1;.) | - |
| NEREIDAE(Larva) | - | - | 12.22(8;18.98) | 4.84(1;.) | - | - |
| NEREIDAE(Juvenile) | 0.24(2;0.14) | 2.41(1;.) | - | - | - | - |
| NEREIDAE(Postlarva) | - | - | - | - | 0.27(1;.) | - |
| NEREIS(Larva) | - | - | - | - | 0.04(1;.) | - |
| NEREIS | - | - | - | - | 21.56(1;.) | - |
| NEREIS SUCCINEA(Larva) | - | - | - | 17.7(1;.) | - | - |
| NEREIS SUCCINEA | - | - | - | - | - | - |
| SPIONIDAE(Larva) | - | - | 41.37(16;58.95) | 115.9(9;200.9) | 2.02(2;2.54) | 47.86(2;36.91) |
| SPIONIDAE | - | - | - | 0.37(1;.) | 1.14(1;.) | - |
| OLIGOCHAETA(Larva) | - | 2.9(3;2.71) | 5.28(3;2.05) | - | - | 2.56(1;.) |
| MOLLUSCA(Veliger) | - | - | 37.14(3;29.26) | 17.6(1;.) | - | - |
| GASTROPODA(Veliger) | 67.6(25;251) | 95.8(7;239) | 82.5(28;233.6) | 151.7(51;364.9) | 225.3(51;912.7) | 31.94(41;48.47) |
| GASTROPODA(Juvenile) | 4.17(2;1.53) | - | - | - | - | - |
| GASTROPODA | - | - | - | - | - | - |
| THECOSOMATA | 0.22(3;0.21) | - | - | 19.44(2;22.48) | - | - |
| BIVALVIA(Veliger) | 35.16(10;43.66) | 3.78(4;4.58) | 37.53(12;114.2) | 125.7(25;314) | 522(46;1298) | 170.4(31;669) |
| BIVALVIA(Juvenile) | - | - | - | - | - | - |
| CRASSOSTREA VIRGINICA(Veliger) | - | - | - | - | 20.85(7;15.91) | - |
| CEPHALOPODA(Larva) | 0.07(1;.) | - | - | - | 0.09(1;.) | - |
| LOLIGINIDAE(Larva) | - | - | - | 0.1(2;0.05) | - | - |
| LOLLIGUNCULA BREVIS(Larva) | - | - | - | 0.06(1;.) | - | - |
| ARACHNIDA(Juvenile) | - | - | 9.96(2;13.85) | - | - | - |
| ARACHNIDA | 1.93(2;2.63) | 1.25(4;0.83) | 3.34(2;3.74) | 14.35(1;.) | 0.11(5;0.08) | 0.2(1;.) |
| ACARINA(Juvenile) | - | - | - | - | 13.45(1;.) | - |
| ACARINA | - | - | - | 0.99(2;1.25) | - | - |
| CRUSTACEA(Egg) | - | - | - | - | - | - |
| CRUSTACEA(Nauplius) | 12770(40;73703) | 684(40;1290) | 539(38;870) | 865(52;2828) | 991(31;1937) | 4989(31;17590) |
| BRANCHIOPODA | - | - | - | - | - | 0.18(3;0.13) |
| CLADOCERA | 221.2(10;385.6) | 97.9(16;162.6) | 122.5(14;178.4) | 68.6(13;95.1) | 407.4(29;766) | 1579(28;2279) |
| SIDIDAE | - | - | - | 25.89(3;29.56) | 0.83(1;.) | 534(2;753) |
| PENILIA | - | - | - | - | - | - |

Table A-2 continued.

| | JULY | AUGUST | SEPTEMBER | OCTOBER | NOVEMBER | DECEMBER |
|---|---|---|---|---|---|---|
| ANNELIDA(Larva) | 1145(1;.) | - | 0.1(1;.) | - | - | 0.08(1;.) |
| POLYCHAETA(Juvenile) | - | - | 38.91(1;.) | 9.3(1;.) | - | 329.9(2;245.6) |
| POLYCHAETA | - | 41.86(1;.) | 68(2;89.3) | 20.38(1;.) | - | 3.11(1;.) |
| POLYCHAETA(Trochophore larva) | 101.2(36;201.4) | 33.62(29;29.25) | 102.8(61;228.9) | 69(49;261.1) | 52.9(54;86.6) | 87.2(52;205.4) |
| POLYCHAETA(Mitaria) | - | - | - | - | - | - |
| ALCIOPIDAE | - | - | - | 0.04(1;.) | - | 0.14(1;.) |
| TYPHLOSCOLECIDAE(Larva) | - | - | - | 13.04(1;.) | - | - |
| TYPHLOSCOLECIDAE | - | - | - | - | 1.12(1;.) | - |
| TOMOPTERIS | - | - | 0.23(1;.) | - | 0.2(2;0.02) | - |
| NEREIDAE(Larva) | - | - | - | - | - | - |
| NEREIDAE(Juvenile) | - | - | - | - | - | - |
| NEREIDAE(Postlarva) | - | - | - | - | - | - |
| NEREIS(Larva) | - | - | - | - | - | - |
| NEREIS | - | - | - | - | - | - |
| NEREIS SUCCINEA(Larva) | - | - | - | - | - | - |
| NEREIS SUCCINEA | - | 0.11(1;.) | - | - | - | - |
| SPIONIDAE(Larva) | 111(1;.) | - | - | - | - | - |
| SPIONIDAE | - | - | - | - | - | - |
| OLIGOCHAETA(Larva) | 0.04(1;.) | - | - | - | - | 0.1(1;.) |
| MOLLUSCA(Veliger) | - | - | - | 67.6(1;.) | - | 0.11(1;.) |
| GASTROPODA(Veliger) | 208.9(45;662.3) | 47.43(53;76.25) | 138.8(63;388.8) | 97.9(43;247.5) | 54.1(27;145.7) | 62.8(17;68.9) |
| GASTROPODA(Juvenile) | - | - | - | - | - | - |
| GASTROPODA | - | - | - | 4.4(2;0.66) | - | - |
| THECOSOMATA | - | - | 1.87(2;2.52) | - | 42.6(3;59.18) | 8.97(1;.) |
| BIVALVIA(Veliger) | 361.3(25;1267) | 93(48;180.4) | 279.6(55;636.4) | 123.1(41;227.5) | 27.34(13;47.26) | 56.2(9;66) |
| BIVALVIA(Juvenile) | - | - | 11.27(1;.) | - | - | - |
| CRASSOSTREA VIRGINICA(Veliger) | - | - | - | - | - | - |
| CEPHALOPODA(Larva) | - | - | - | - | - | - |
| LOLIGINIDAE(Larva) | 0.06(1;.) | 0.08(1;.) | - | - | - | - |
| LOLLIGUNCULA BREVIS(Larva) | - | - | - | - | - | - |
| ARACHNIDA(Juvenile) | - | - | - | - | - | - |
| ARACHNIDA | - | 1.27(1;.) | 0.48(5;0.39) | 12.36(1;.) | - | - |
| ACARINA(Juvenile) | - | - | - | - | - | - |
| ACARINA | - | - | - | - | - | - |
| CRUSTACEA(Egg) | 476.6(1;.) | - | 166.1(2;191.7) | 79.4(1;.) | - | - |
| CRUSTACEA(Nauplius) | 1491(23;1760) | 1529(23;4018) | 1466(17;2733) | 1669(22;2676) | 950(28;2291) | 302(20;372.7) |
| BRANCHIOPODA | - | - | - | - | - | - |
| CLADOCERA | 824(23;1508) | 243.6(29;703.9) | 3809(12;12941) | 26.51(7;26.92) | 8.43(2;8.76) | 120.3(7;295.5) |
| SIDIDAE | - | - | - | - | - | - |
| PENILIA | - | 16.23(1;.) | - | - | - | - |

Table A-2 continued.

| | JANUARY | FEBRUARY | MARCH | APRIL | MAY | JUNE |
|---|---|---|---|---|---|---|
| PENILIA AVIROSTRIS | 260(2;356.7) | 0.33(2;0.18) | - | 1010(4;1124) | 90.6(5;138.8) | 1085(6;2213) |
| DAPHNIIDAE | - | 14.83(2;6.94) | 40.02(2;34.89) | 1.87(1;.) | - | 167.4(2;88.6) |
| BOSMINIDAE | - | 29.64(2;25.08) | 87(3;106.2) | 86(5;147.6) | - | - |
| EVADNE | - | - | - | - | 10.4(2;3.79) | - |
| EVADNE TERGESTINA | - | 39.01(5;72.2) | 672(9;1028) | 14.2(1;.) | 9.58(2;12.99) | - |
| PODON | - | - | 4.41(1;.) | - | - | - |
| PODON POLYPHEMOIDES | - | - | 32.85(3;35.22) | - | - | - |
| CHYDORIDAE | - | 13.85(2;2.75) | 19.61(5;23.52) | 25.55(2;14.98) | 149.6(2;35.7) | - |
| MACROTRICHIDAE | - | - | - | - | - | 86.9(1;.) |
| OSTRACODA | 49.44(17;135.3) | 14.9(14;19.88) | 28.36(24;49.15) | 27.48(27;33.86) | 54.9(32;115.5) | 52.7(27;147.3) |
| COPEPODA(Nauplius) | 328.7(51;702) | 807(40;2188) | 298.2(51;348.9) | 704(49;1116) | 9223(79;41066) | 287.8(66;357.8) |
| COPEPODA | 2202(42;4529) | 1241(39;1474) | 1116(49;1699) | 2331(61;5497) | 1044(39;1829) | 1761(36;3901) |
| COPEPODA(Copepodid) | 458.6(24;949.5) | 301.8(31;748.3) | 995(24;1396) | 865(29;855) | 3430(29;4735) | 3469(32;3719) |
| CALANOIDA | 102.4(11;128.8) | 63.8(21;136.4) | 27.36(15;32.47) | 119.1(21;273.2) | 868(45;1186) | 969(37;2388) |
| CALANOIDA(Copepodid) | - | 87.9(1;.) | 103.5(6;165) | 34.59(3;26.74) | 66.7(1;.) | - |
| CALANUS | - | - | - | - | - | - |
| CALANUS MINOR | - | 0.2(1;.) | 0.07(1;.) | 0.25(3;0.13) | - | - |
| UNDINULA VULGARIS | 4.28(1;.) | 6.42(2;6.1) | 4.98(2;6.52) | 3.96(6;5.34) | - | - |
| UNDINULA VULGARIS(Copepodid) | - | 0.81(1;.) | - | - | - | - |
| EUCALANUS | 1.86(2;2.53) | 5.23(1;.) | 27.77(2;38.93) | - | 10.89(6;6.83) | 56.4(3;93.3) |
| EUCALANUS(Copepodid) | 8.99(1;.) | - | 5.21(2;3.9) | - | - | - |
| EUCALANUS ATTENUATUS | - | - | 0.12(1;.) | 0.05(1;.) | - | - |
| EUCALANUS ATTENUATUS(Copepodid) | - | - | - | 1.94(1;.) | - | - |
| EUCALANUS PILEATUS | - | - | - | 84(5;136.6) | 3.19(1;.) | - |
| EUCALANUS PILEATUS(Copepodid) | 7.34(1;.) | - | 6.76(3;8.14) | 8.8(4;8.77) | 61.4(3;63.7) | 4.53(1;.) |
| RHINCALANUS | - | - | 0.46(1;.) | - | - | - |
| RHINCALANUS(Copepodid) | - | - | 0.31(1;.) | - | - | - |
| RHINCALANUS CORNUTUS | 4.86(1;.) | - | 1.74(1;.) | - | - | - |
| PARACALANIDAE | - | - | - | - | - | 3.13(1;.) |
| PARACALANUS | - | 9.68(3;15.46) | 8.77(2;4.64) | 80.5(3;54.7) | 26.48(1;.) | 155.8(3;96.3) |
| PARACALANUS(Copepodid) | - | - | 1.93(1;.) | - | - | - |
| PARACALANUS PARVUS | 100.5(4;90) | 86.9(1;.) | 24.23(8;32.57) | 79.1(9;136.9) | 12.75(1;.) | - |
| PARACALANUS PARVUS(Copepodid) | 22.48(2;25.7) | - | 5.14(2;1.03) | 33.04(2;2.7) | 28.83(1;.) | - |
| PARACALANUS CRASSIROSTRIS | 145(13;257.9) | 1449(2;2049) | 120.5(21;204.2) | 781(13;1393) | 1159(9;2109) | 257.8(4;300.9) |
| PARACALANUS CRASSIROSTRIS(Copepodid) | 13.48(2;8.71) | 2.27(6;1.82) | 35.85(11;68.01) | 107.9(6;133.8) | 545(3;280) | 31.66(2;27.05) |
| PARACALANUS ACULEATUS | - | - | - | - | - | - |
| CALOCALANUS | - | - | - | 0.55(1;.) | - | - |
| CALOCALANUS PAVO(Copepodid) | - | - | - | 3.88(1;.) | - | - |
| ACROCALANUS LONGICORNIS | - | - | - | 0.32(2;0.07) | - | - |
| CLAUSOCALANUS FURCATUS | - | - | - | 11.79(2;16.3) | - | - |